RADIUS PROJECT OF GUAYAQUIL - ECUADOR

Risk Assessment tools for Diagnosis of Urban areas against Seismic disasters

Municipality of Guayaquil

The Secretariat of the International Decade for Natural Disaster Reduction (IDNDR 1990-2000) United Nations

GeoHazards International

IIFIUC, Research and Development Institute of the School of Engineering of Universidad Católica of Guayaquil - Ecuador

GUAYAQUIL CITY FINAL REPORT

INDEX

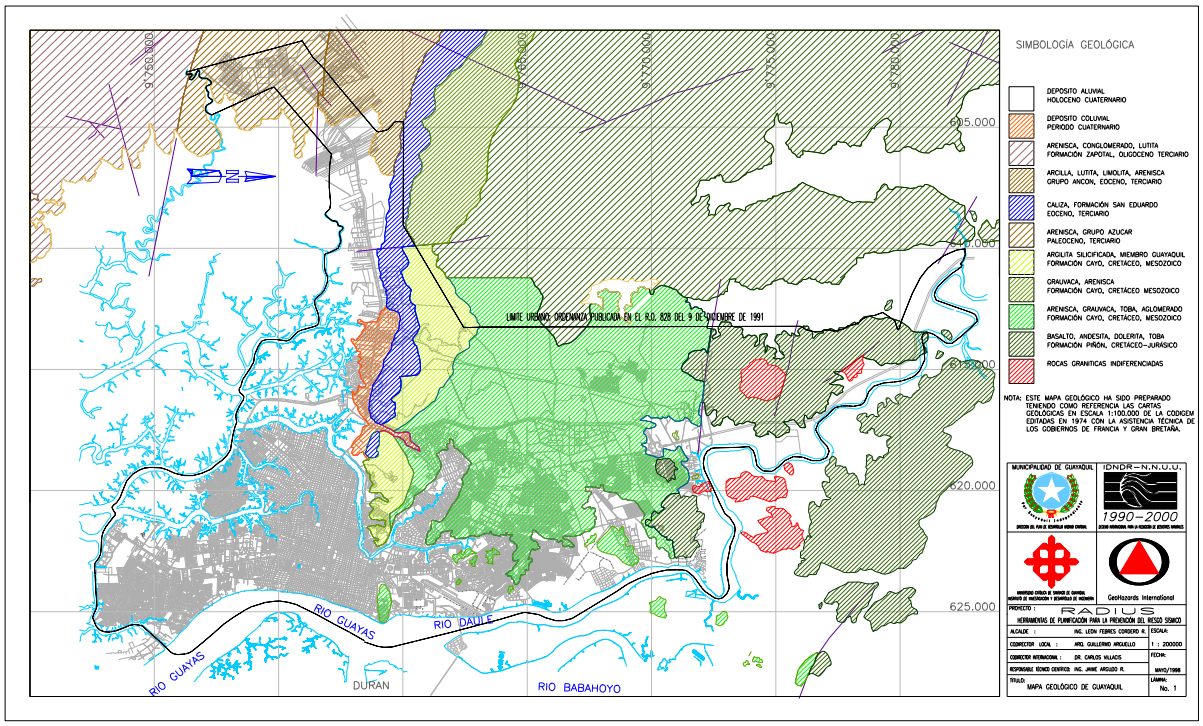
CHAPTER 1: INTRODUCTION

1.1. GENERAL DESCRIPTION OF THE CITY

Guayaquil lies on the west bank of the Guayas River over deposits of alluvial soil and sedimentary rock. The City has grown to the South, making artificial fills with material from rock deposits on the marine estuaries that were originally covered by mangroves.

It is located in the farthest southern part of the Guayas River basin, limited to the east by the Andes Mountains and to the west by the Chongon-Colonche mountains. The eastern tip of the Chongon-Colonche mountains ends in the City of Guayaquil which is formed by sedimentary rocks that reach an altitude of 800 meters.

The urban area of Guayaquil is 33,825 hectares. The total area (including the rural zones) is 500,706 hectares. Map 1 shows the location of the City within the urban limits and the different Geological formations over which the City is placed.



Map 1. Geology and City limits of Guayaquil. [7]

The weather in Guayaquil is hot and humid, with two well defined seasons: “rainy season” from January to May and “dry season” from June to December. The average temperature is 21°C with extreme values ranging from 18°C to 36°C.

The relative humidity is 50%, but in the months between January and May it reaches 97%. The dominant winds follow the South-west direction. The average annual rain fall is 1,000 mm, with higher values during the El Niño seasons when values in excess of 4,000 mm have been recorded.

1.2. DEMOGRAPHIC DATA

The population of Guayaquil registered during the last census of 1990 was 1’508,440 inhabitants. There are two neighboring areas that have been integrated to the city which belong to the municipalities of Samborondon and Duran. These areas are considered as part of the metropolitan area of Guayaquil.

In 1997 a population of 2’129,000 was estimated. The official annual growth rate of the population is 3.2% for Guayaquil and 3.54% for the entire metropolitan area. By the end of 1999 the population of the metropolitan area will be over 2’500,000 inhabitants. After the disasters caused by El Niño during 1997 and 1998, almost 300,000 people immigrated to the city within the last two years.

In map 2 the population density is seen for each cadastral sector. The majority of the people live in dense sectors to the north, south and west of Guayaquil.

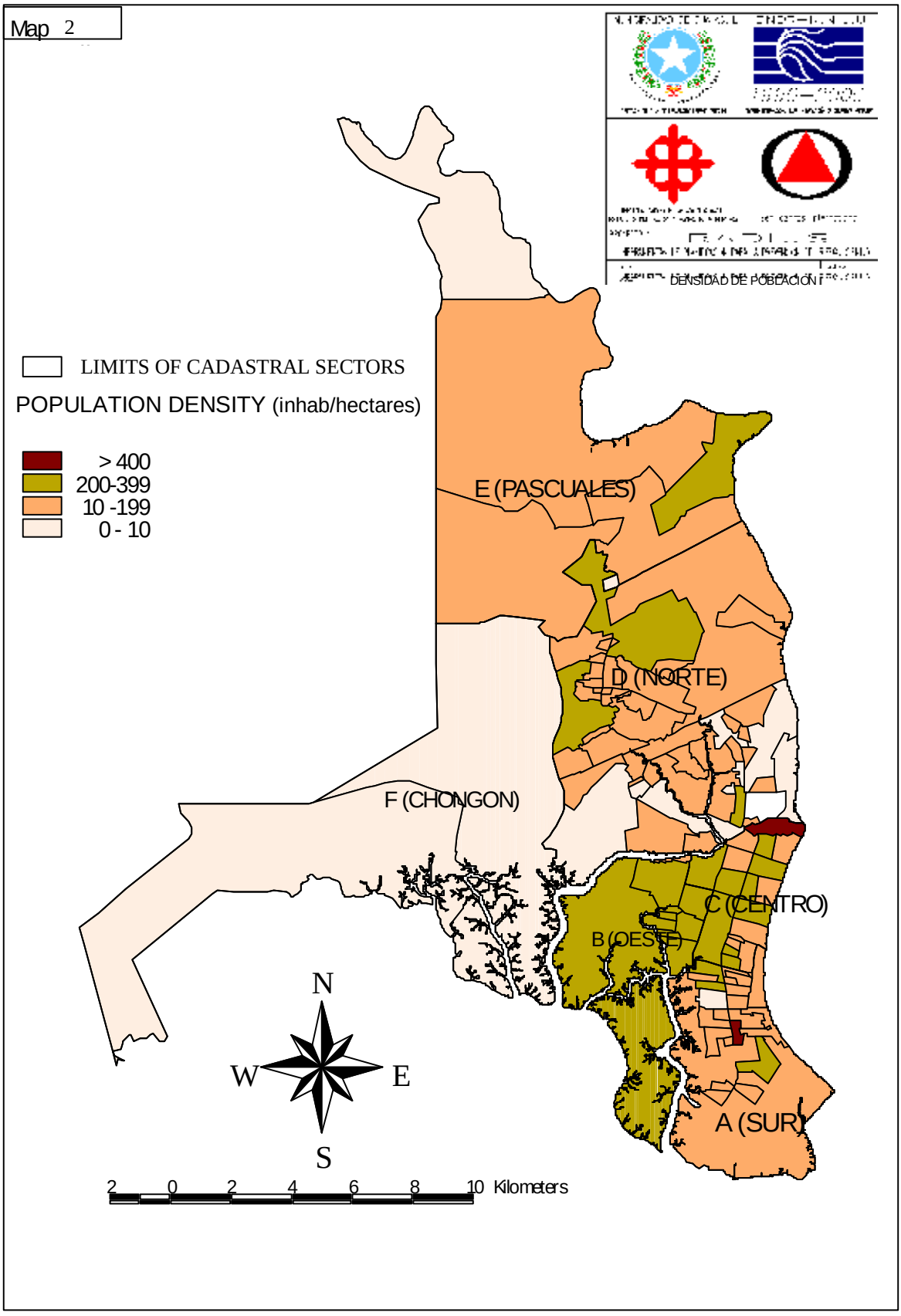
1.3. ECONOMY

Guayaquil is the main industrial and commercial city of Ecuador, it concentrates more than 40% of the 100 main industrial and commercial companies of the country.

In 1995, the Office of Urban Development Plan of the Municipality of Guayaquil (DPLAN-G) estimated that for that year the GNP (Gross National Product) of the City was US $ 2,782 million dollars, about 20% of the GNP of the country. The main commercial activities of the City of Guayaquil are presented in table 1.

Additionally, the City operates the main sea port of Ecuador, which moves 60% of the import and export commerce of the country.

The major parts of the commercial and financial activities are concentrated to the east of the City, in the so called “Central Zone”, located near the west bank of the Guayas River, where the largest commercial value of buildings are also located. See figure 1 and map 3.

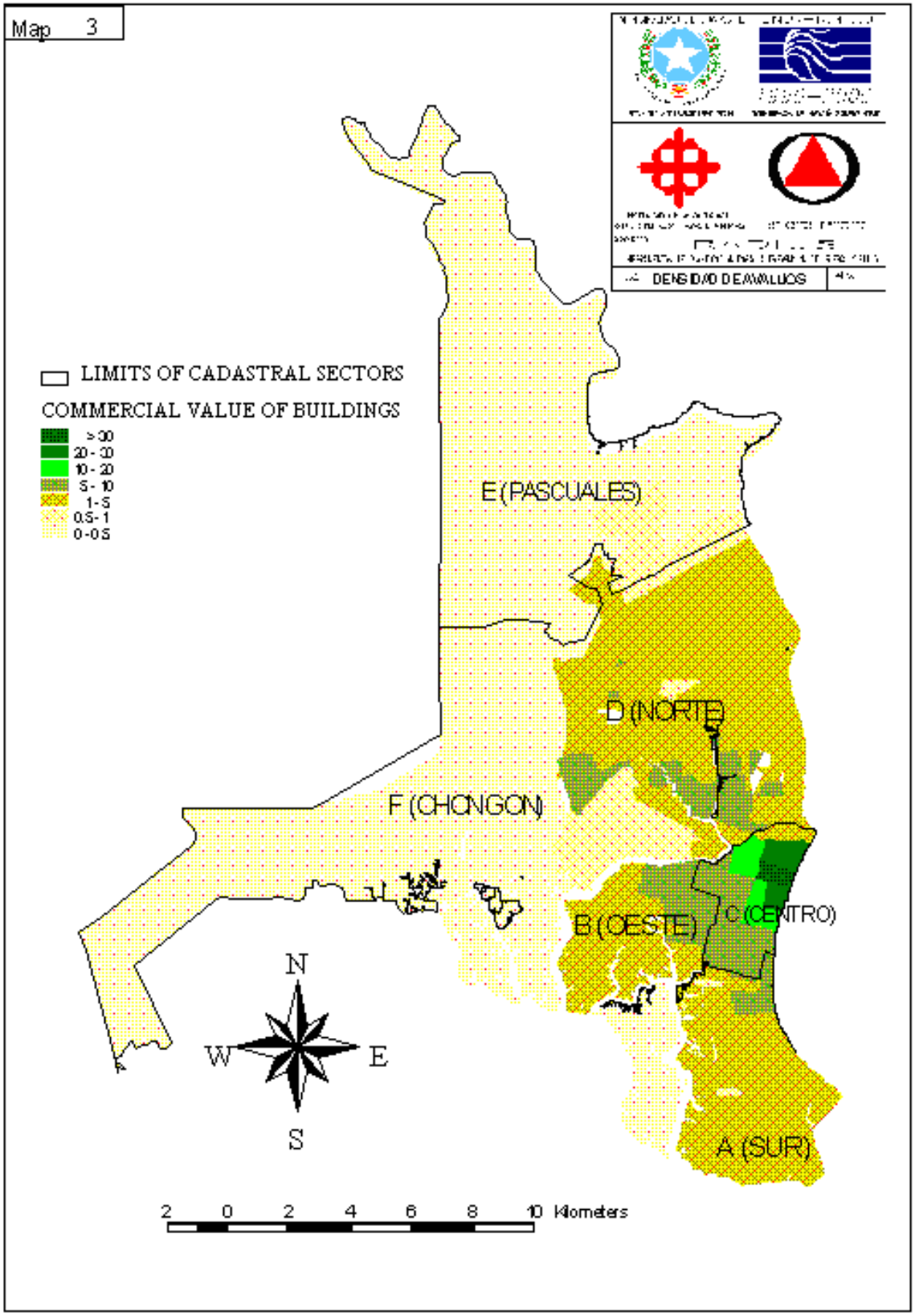


Map 2. Population density by sectors in Guayaquil

Table 1. Main commercial activities of Guayaquil, population involved and participation percentage of the GNP of the City.

ACTIVITY	POPULATION INVOLVED	% GNP
Agriculture, fishing industry, hunting	23,435	4.10
Mining	618	0.10
Manufacturing Industry	72,628	12.60
Electricity, energy and water	2,523	0.40
Construction	41,813	7.30
Business	133,631	13.20
Transportation and communications	30,798	4.00
Finances and insurance	31,128	5.40
Services	162,785	28.30
Not well defined activities	65,365	11.40
Non-traditional activities	10,392	1.80

Figure 1. Panoramic View of the "Central Zone", where the largest part of the commercial and financial activity of the City is concentrated.



Map 3. Density of commercial value of buildings in Guayaquil

CHAPTER 2: DISASTERS IN THE CITY

2.1. HISTORICAL DISASTERS

2.1.1. The Great Fire of October 5, 1896

In the great fire of October 5, 1896 more than half of the City was reduced to ashes. The Parroquias (City Districts) of Carbo and Rocafuerte burned totally. These Parroquias are currently the heart of the "Central Zone" and at that time represented more than half the size of the City. The neighborhoods of Barrio Las Peñas and the peripheral areas were spared, as shown in figure 2.

This has been the greatest disaster that Guayaquil has suffered during its recorded history. It represents a major turning point to the current architectural and urban configuration of the City. Many reinforced concrete buildings began to be constructed since the first decade of the XX century.

Although this material is not well suited for the warm climate of Guayaquil, it represented the safest option to get away from the menace of fire and it rapidly replaced wood as the preferred material for the Guayaquil people. In 1896, 99% of the City was built with wood, today 70% of all buildings are made of reinforced concrete and a little less than 30% are made of wood.

Figure 2. Guayaquil after the great fire of 1896. The zones marked in black were burned from the Parroquias of Carbo and Rocafuerte, where the commercial and financial Center of the City now stands [17].

2.1.1. The earthquake of May 13, 1942

At 21:06 of May 13, 1942, an earthquake of Richter magnitude Ms=7.9 occurred in the Pacific Ocean, near Jama in the northern coast of the Province of Manabi. It affected the entire country, but in particular affected Guayaquil where the phenomenon of "local site effect" was produced with the amplification of the vibrations of the soft soil of Guayaquil.

After the earthquake, a maximum Intensity of IX was reported in the modified Mercally Scale, due to the damage inflicted to a few reinforced concrete structures in the central zone of the City. In other buildings located in the central, southern and western part of the City, also built on soft soil, an Intensity of VIII was observed. An Intensity of VI was reported on rock sites.

A strong oscillatory movement was felt which started very weak at first but in a short time the movement grew in intensity. The movie houses and theaters were abandoned in a hurry by the people who suffered only minor injuries. The inhabitants of the City went out to the streets and many people spent the night outdoors. Entire families slept in the Parks of Centenario, Seminario, Montalvo, Calderon, Chile and España, as well as inside the cars. All lights of the City were turned off.

There were 40 people who died, the main cause being crushing, because of the total collapse of buildings. Forty three persons were taken out alive from the debris of the buildings, 21 of them fatally injured. There were 11 people injured in other parts of the Central Zone, the majority of them because of fallen debris from walls or roofs. The largest number of deaths occurred in the total collapse of a five story building where Clinica Arreaga was functioning. See figure 3.

The largest losses occurred to reinforced concrete buildings, three buildings of 4 to 5 stories collapsed and many buildings of more than 3 stories suffered a lot of damage, five of them were later demolished [15]. Other buildings suffered different degrees of damage: cracking of columns and walls, falling of facades and walls, interior damage and inclined buildings. The majority of damage always occurred on the first and second floors. See figure 4.

The damage in wood buildings were mainly produced by the so called "mixed" structures formed by wood frames filled with heavy clay bricks put together with mortar. The damage ranged from total destruction to numerous cases of fallen debris of facades and walls. This kind of damage was observed all over the City, but the largest damage was found to the south where the quality of construction was very poor.

The damage to lifelines was not less intense than those to buildings, nobody died due to them, but a many losses and disturbances to the normal function of the City were observed. Power lines and power cables to the electrical rail cars were pulled off in the sector of Colon and Pichincha streets causing many power short-circuits.

All the lights of the City were turned off suddenly, after the earthquake, when the power was reestablished partially, many sectors remained in the dark.

A light post fell and many iron posts from the power and telephone lines were bent. There were multiple power short-circuits and power lines ripped away along Avenue 9 de Octubre up to Lorenzo de Garaycoa street; the Power Company decided to interrupt the service after the earthquake to avoid fires produced by the power short-circuits. The telephone lines were also ripped away and the automatic service of fire alarm was interrupted in the Central Fire Station.

There was malfunctioning of the water pipe lines in the urban as well in the rural areas. Many leakage points were located in the 22 in. rural pipe lines, in Casiguana and to the mouth of Yaguachi River. There were also three leaks in the pipe line of 11 inches in Km. 26 and in the sector between Duran and Yaguachi. The pipe line under the Yaguachi River was disconnected.

There was a reduction of water supply to the City from 06h00 to 09h00, from 11h00 to 13h00 and from 16h00 to 20h00. The breaking of the many pipes all over the City were completely repaired a week later. Many pumps of the fire department were cut out along Avenue 9 de Octubre up to Lorenzo de Garaycoa street.

Parker Clinic received more than forty people wounded and all hospital of the City were declared in emergency status.

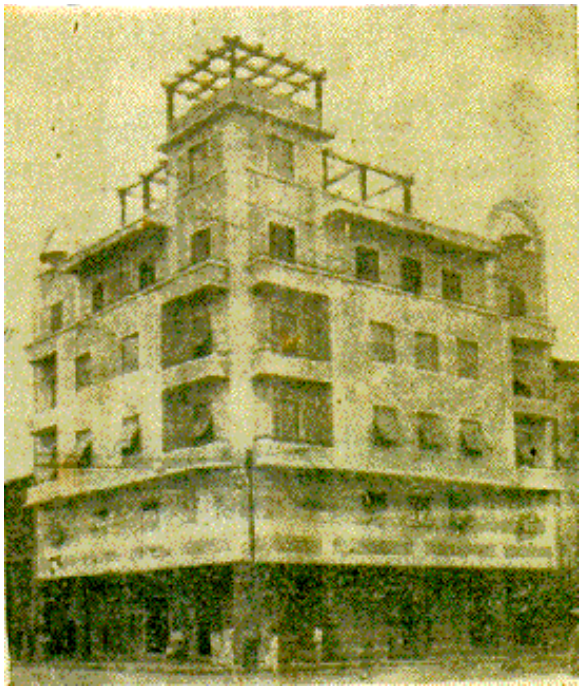


Figure 3. Building of Arreaga Clinic that collapsed during the earthquake.

Figure 4. Building of Hotel Pauker. It suffered heavy damage and was ordered to be demolished in 1942.

2.1.3. The earthquake of August 18, 1980

The earthquake occurred at 10:08 am of August 18, 1980. A Richter magnitude of Ms=6.1 was reported and the epicenter was located in the small town of Nobol, 30 Km away from Guayaquil. The Modified Mercalli Intensity was estimated at VII degrees.

This particular earthquake occurred during working hours of the city and it left many useful lessons to help us understand the possible impact of an earthquake of Intensity VIII in present times. This was the only earthquake in the history of the city that forced the closing of schools, the evacuation of all students from school buildings and urban traffic jams caused by desperate parents trying to reach the schools where their children were studying.

There were 10 people dead and more than 100 people wounded or injured. Almost 90% of all the people who died of serious injury were a result of falling debris from brick walls from the so called "mixed" houses. More than 100 houses and buildings were destroyed or heavily damaged. In 1980 Guayaquil had a population of 1'100,000 inhabitants, 5,200 City blocks and a total area of 9,000 hectares. Currently, the population is well over 2'500,000 inhabitants and there are more than 18,000 City blocks with an urban area in excess of 33,000 hectares.

The aftermath of the earthquake: 49 "mixed" houses had to be demolished in the Parroquias of Bolivar, Ayacucho, Sucre and Garcia Moreno, in the Central and South Zones of the City. If we consider that the earthquake was reported with an Intensity of VII degrees, it must be accepted that a future earthquake with an Intensity of VIII degrees would destroy the majority of these houses. The age of the affected structures ranged between 20 and 40 years old. Nowadays the structure of these houses has deteriorated and many of them are over 40 years old. See figure 5.

None of the reinforced concrete buildings suffered structural damage, some of them suffered non-structural damage with the cracking of masonry walls, small cracks on structural elements, breaking of window glasses, falling of decorative and ornament objects and false ceiling damage.

The majority of the affected reinforced concrete buildings had four or more levels, some of them were reported with small deviations from the vertical line due to the characteristics of their foundation, and others experimented damage due to some kind of architectural complexity, not recommended for aseismic construction: non-symmetric design in elevation and in plan, soft stories, glass facades (curtain walls) and large cantilever balconies.

The damage suffered by the schools of the City deserve special attention. Almost all of them are reinforced concrete buildings. A week later after the earthquake, 24 high schools and 34 elementary schools, almost 8% of all schools, were not allowed to restart classes because they did not pass inspection.

This is a very high percentage of affected schools for an earthquake of I=VII, which makes the vulnerability of educational buildings clear.

The windows and shelves of commercial stores in the Central Zone were destroyed, and because of that almost all commercial activities in that zone of the City were interrupted. The basic services (transportation, telephone and power) were suspended and they were reestablished between 10h30 and 13h00. There were many people trapped in elevators of some buildings.

The traffic was interrupted in one sector due to the falling of one power post and there were more than 100 reports of fallen power and telephone posts. Telephone communications were shut down for one hour and they were not fully reestablished until noon.

However, the repairing of some telephone lines took from two to three weeks after the earthquake. The entire City had 50,000 telephone lines. The aqueducts did not suffer any damage. There was no damage done to the pipe lines and the water supply was normal, with small interruptions in the potable water system.

There were no fires reported due to the falling of power posts, but the Fire Department received 15 emergency calls for small fires or people injured. All calls came from the four Parroquias with major damage. There was a traffic jam because of people hurrying to get to some places, the lack of power caused the interruption of the service of traffic lights and also because of the absence of traffic policemen in the streets. The public transportation system was interrupted for three hours. The Central Radio Station of the local Traffic Police was interrupted due to power failure and because of the falling of some cables.

Hospitals were fully active and were declared in emergency status, calling all personnel to go to the hospitals. The medical centers that received the most patients were: General Luis Vernaza, Abel Gilbert (Guayaquil) and Teodoro Maldonado (IESS). There were numerous cases of nervous breakdowns and the police was needed to control order in the hospitals. Hospital Guayaquil managed 31 emergencies, 16 of them critically injured. In Hospital Vernaza there were 29 critically injured people of a total of 50 patients. Hospital IESS treated a total of 48 people injured. Some pregnant women were interned in shock to Maternidad Enrique Sotomayor.

Medicine supplies for nervous cases run out of stock in the City during the first day. All emergency rooms worked normally. Hospitals and Clinics did not suspend service. The response of all hospitals and clinics and public services was good, but it was noticeable that an earthquake of I=VII took them to their limits of capacity.

During the last 20 years, the capacity to attend emergencies of hospital has increased in less than 50% and the public services have increased a lot in complexity and size. However, the City has grown 2.5 times in inhabitants, 3.5 times in the number of buildings, and the Intensity of an earthquake similar to that of 1942 would be much larger than a similar to the 1980´s earthquake, reaching a degree of VIII.

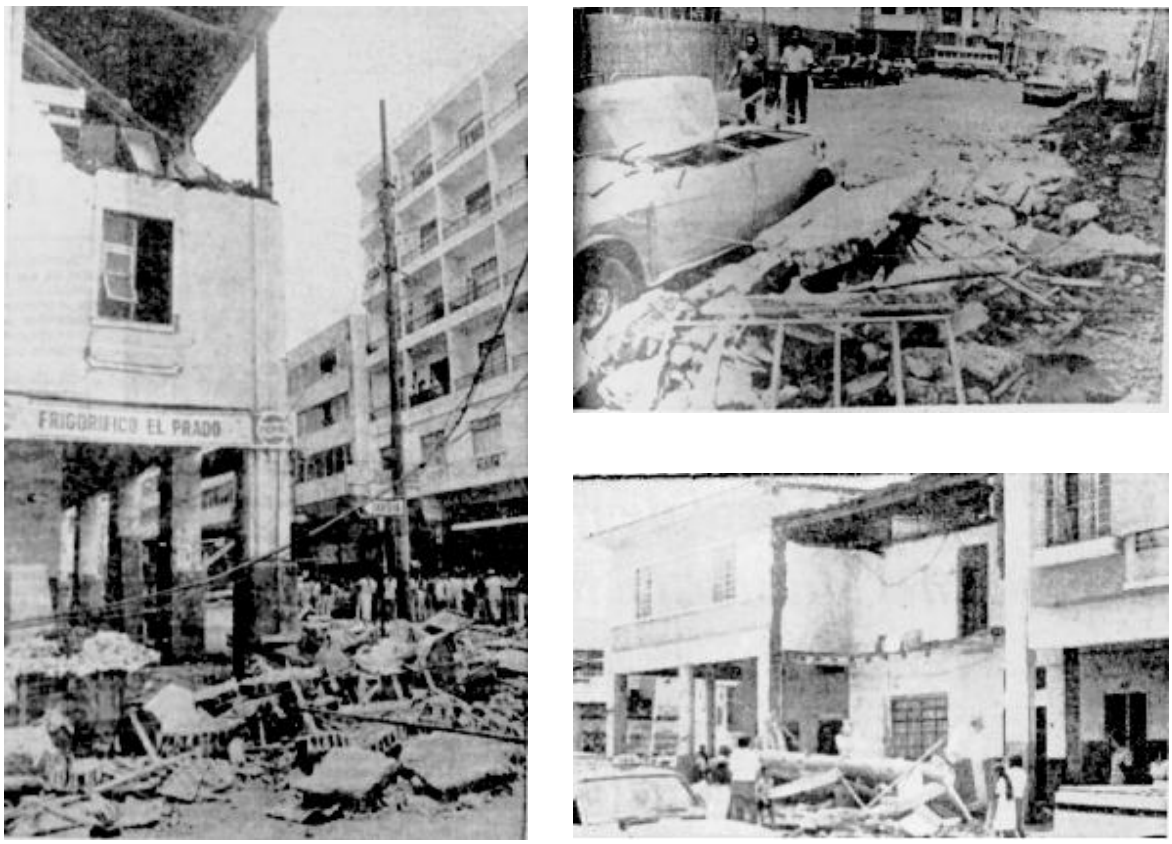


Figure 5. Damage in "mixed" structures during the earthquake of August 18, 1980.
Source: Diario El Universo de Guayaquil (IIFIUC archives – Project RADIUS)

2.2. CURRENT SITUATION OF THE CITY FACING EARTHQUAKES

2.2.1. Unplanned urban growth, risk and lack of preparation.

Unplanned growth of the city is one of the main reasons that the risk has increased significantly over the last years. The occurrence of an earthquake of magnitude equal or greater than that of May 13, 1942 has a 53% probability within the next 50 years, that would produce an Intensity of VIII degrees in the Modified Mercalli Scale.

For an Intensity of VIII one should expect minor structural damage in well designed reinforced concrete building and in wood or cane constructions which are very light in weight, moderate damage in reinforced concrete structures without seismic design, and major damage with possibility of collapse in "mixed" buildings.

If we make a correlation between the current population and the statistics of people injured during the 1942 earthquake, the number of people dead and injured would rise to over 1,000 persons.

However, the number of fatalities in the current conditions could be much larger, because the present vulnerability of the city has grown due to the aging of many buildings (see figure 6), and also because of informal construction with heavy materials without seismic provisions and the lack of application of seismic design codes (see figure 7).

The city is not prepared to face the effects of an earthquake of Intensity VIII.

Figure 6. "Mixed" houses have the highest risk of collapse, many of them are over 40 years old, and their wood structure has deteriorated with poor confinement of brick walls within the wooden frames. There are more than 200 buildings of this type in the Central Zone of the City.

Figure 7. Condominium BEV-BM6. Especially in the North Zone, many reinforced concrete structures do not follow seismic codes. This structure is located in Sauces IX, and has been remodeled without technical supervision. The result is the increase in its seismic risk in a zone initially characterized by its low risk [2].

Some of the aspects that denote the lack of preparation of the City to face earthquakes are:

a) Lack of municipal ordinances that rule the seismic aspects of construction, the reinforcing of seismic resistant structures or the demolition of obsolete structures without possibility of reinforcing them.

The falling of debris from walls and facades of the "mixed" houses is the main cause of fatalities during an earthquake, as seen in 90% of the cases during the earthquake of August 18, 1980. 10% of more than 300,000 buildings of the city are "mixed" structures, and one fourth of them are obsolete structures, many of them would collapse partially or totally. The risk of fire is very high in these buildings because their electrical installations are old and dangerous.

A municipal plan done to the urban recovery of the Central Zone is helping in the risk mitigation of these buildings, one of the planned actions deals with the demolition of these structures due to their low cadastral value and other related social problems (informal commerce, insalubrity, etc.)

b) The more important life lines (water, electricity and telephone) are sensible to the service they provide due to the possible damage in their critical points and because of the strong dependence that they have with respect to other systems or vulnerable elements.

The system of water distribution through the use of pipes can suffer severe rationing due to probable breaking in the four aqueducts that go through different type of soils without devices to dissipate relative deformations during earthquakes. The facilities of "La Toma" work with electric power only. The power supply for the City depends in 50% upon the contribution of the Paute Hydraulic Dam through the National Interconnected System.

The telephone system has the "Central Centro" and the "Transmission Tower" of Santa Ana Hill as its critical points, with 100% of the telephone communication being operated through those two facilities. The "Central Centro" is located in an old building without seismic design and with a background of damage in the earthquake of March 1946. Furthermore the tower of Santa Ana Hill is located over a slope prone to landslides.

c) The basic organizations of the city that operate essential services for emergency situations (Civil Defense, Red Cross, Police, Transit Police, Fire Department and Armed Forces) do not have a contingency plan for earthquakes.

With the exception of the Armed Forces, the personnel of these organizations is not well trained. Their rescue equipment is small and they cover less than 50% of the population´s needs during normal situations as a result of their deficit in personnel and equipment during emergencies.

The facilities that house many of the essential services (Fire Department Stations, Civil Defense and Red Cross) are not seismic resistant structures. They have many risk factors that predict their strong to moderate damage during an earthquake.

d) The hospitals have a noticeable deficit of beds for hospitalization. There are a few public or private hospitals (four of them) that are equipped with services for attending to emergencies, but the majority of hospitals (75%) could be not operational after an earthquake due to the vulnerability of their life lines and equipment. There is no contingency plan for earthquakes in the health sector, being this the most vulnerable point of the city in the scenario of an earthquake disaster [3].

e) The institutions with the capacity of action in the recovery of the city and the post-disaster social assistance (Municipio, INNFA, Ministry of Welfare, Education, Housing, Church, and the private sector) do not have a policy or plans of action in the case of an earthquake.

The INNFA child care units as well as the essential facilities and hospitals, temples and schools gather some factors that put their buildings on a high risk of experiencing major damage with respect to others. In particular, church and school buildings have a long history of damage as seen during the earthquakes that have occurred in the present century.

It may be concluded that the majority of deaths and the social post-disaster impact are produced as a consequence of the collapse of a reduced number of buildings, because of the damage to vital and essential systems of the city, and the lack of preparation and rapid response action.

In Guayaquil, although informal construction is very extensive and seismic codes are not applied, the majority of buildings are safe enough. Buildings of wood or cane constructions (20%) have a very low risk because they are very light in weight. Reinforced concrete houses of 1 or 2 floors (60%) also have low risk due to the nobility of this material.

In contrast with the former paragraph, one fourth of the city's population is in school aged and goes to nearly 1,500 schools buildings; all the blood reserve of the city that the Red Cross operates (700 pints) is stored in a building designed without any seismic provisions; there are only 22 fire stations for the combat of fires, most of them have facilities vulnerable to earthquakes; etc.

The preparation of the city demands planning and public awareness to produce a cultural change to do away with the belief that disasters are inevitable, and to understand that disasters may be reduced and that people can act decisively in their mitigation.

2.2.2. Urban Policy and Disaster Management

The Urban Policy of Guayaquil follows the "Urban Development Plan" that has been prepared by the Office of Urban Development Plan of the Municipality of Guayaquil (DPLAN-G), with the technical and financial assistance of the United Nations Development Program (UNDP) in 1994. The disaster reduction has not been considered in this plan.

RADIUS has identified the following areas that must be attended in the City to reduce the seismic risk:

a) Forming a special technical unit in the Municipality of Guayaquil.

It is absolutely necessary that the Municipality of Guayaquil, as the organization that governs and controls the urban development of the City, forms the "Unit for the Reduction of Natural and Non - natural Hazards", on the basis of the experience of the former "Inter Departmental Commission for the management of the emergency of El Niño 1997 – 1998" and the RADIUS Project.

This unit must have as a vertical axis the planning of the low vulnerability county and urban development, the code development and strengthening of the control mechanisms of physical, industrial and environmental safety in the city and in the county, the public communication and community education, and the coordination of municipal actions with other institutions of the Civil Defense System.

Due to its importance in the ambit of planning, the unit should be inserted in the organization of the Office of Urban Development Plan of the Municipality of Guayaquil (DPLAN-G), and because of its close relation to environmental issues, public preparation, buildings and industrial facilities safety construction control and the execution of minor civil works for the reduction of risk at community level, it must have the participation and permanent technical assistance of the following Municipal Departments: Civic Promotions, Press and Advertising; Environmental; Urban, Cadastral and Register; and, Public Works.

One fundamental mission of this unit would be the coordination of the execution of the "Action Plan for the Reduction of Seismic Risk" that RADIUS is preparing for the city, based on the initiatives proposed by more than 50 institutions that participated in the making of this plan.

b) It is recommended that the Municipality of Guayaquil establishes a code for the seismic resistant design of structures. This will make it possible to strengthen the control over informal construction and to better the approval of construction permits for new buildings, as well as the checking of safety of existing structures and to determine either demolition or strengthening of special cases.

CHAPTER 3: ORGANIZATION OF THE GUAYAQUIL - RADIUS CASE STUDY

3.1. OBJECTIVES OF RADIUS

The objectives of the RADIUS Case Study are the following:

a) Evaluate the seismic risk and develop a hypothetical damage scenario due to an earthquake;
b) Prepare an Action Plan based on the results of the evaluation of the seismic risk;
c) Increase public awareness in the people and in the authorities about the seismic risk; and,
d) Initiate an institutionalization process to give support to the efforts of seismic risk reduction and mitigation.

3.2. SCOPE OF WORK

Such scope is the following:

a) To research on damage caused by historical earthquakes in structures and lifelines in Guayaquil, and to make a probabilistic study about seismic hazard of the city.
b) To study vulnerability factors of "elements at risk" of buildings and lifelines in the city, and vulnerability functions to estimate their damage.
c) To perform a "damage simulation" using a Geographical Information System (GIS) for the hypothetical earthquake selected from the seismic hazard assessment.
d) To research on practical knowledge about functioning of lifelines and essential services for emergency management, performing 20 interviews with operators of such systems.
e) To prepare an "Earthquake Scenario" in simple terms to be understood by the community, using the outcomes of the "damage simulation" and the "interview process".
f) To prepare a "Plan for Seismic Risk Management" and an "Action Plan" with the representatives of important institutions of the city.
g) To organize two workshops with representatives of relevant institutions of the city in order to review the Seismic Scenario and the Action Plan.
h) To inform Guayaquil's people through press about advances and outcomes of the project.

3.3. BUDGET

The Municipality of Guayaquil received from the International Decade for Natural Disaster Reduction (IDNDR) of the United Nations the amount of US $ 50,000 making the commitment to execute the RADIUS Case Study.

The Municipality of Guayaquil assigned another US $ 50,000 to the project and through a Special Agreement with Universidad Catolica of Guayaquil put this institution in charge of the execution of the technical studies for the RADIUS Project.

Table 2. Budget of RADIUS Project in Guayaquil

	Concept	Contribution IDNDR – UN	Contribution Municipality of Guayaquil
1.	Personnel	45,000.oo	45,000.oo
2.	Workshops, supplies, publications, etc.	5,000.oo	5,000.oo
	Total (US$) =	**50,000.oo**	**50,000.oo**

3.4. WORK SCHEDULE

The project cronogram (timetable) can be seen in table 3.

Table 3. Timetable of the Project

Start of Project: Feb 1, 1998	Months								
	Feb/98		May/98			Aug/98		Oct/98	
	1	2	3	4	5	6	7	8	9
Preparation of Seismic Scenario									
1. Gathering of information, forming of work groups and Steering Committee									
2. Development of seismic intensity map based on the seismic intensities observed in past earthquakes									
3. Inaugural Meeting									
4. Data preparation for the process of damage estimation using a GIS									
5. Investigation of damage functions and vulnerable elements at risk									
6.Interviews with critical facilities operators									

Continuation from: Nov 1, 1998 End of Project: July 31, 1999	Months Nov/98 Jan/99 May/99 Jul/99 10 11 12 13 14 15 16 17 18
Seismic Scenario and Action Plan	
7. Preparation of Damage Seismic Scenario	
8. Workshop on the Earthquake Scenario	
9. Writing reports on the seismic risk, the damage diagnosis, and the seismic scenario in simple words	
10. Meetings with institutions for the preparation of the Action Plan	
11. Workshop on the Action Plan	
12. Writing of final reports on the seismic risk, Earthquake Scenario, Risk Management - Action Plan to reduce risk	

3.5. RADIUS PERSONNEL

3.5.1. The Steering Committee

The Steering Committee is responsible for the coordination and supervision of the technical studies and administrative work for the satisfactory execution of the RADIUS Project Case Study for the city of Guayaquil. It was formed by Guayaquil Mayor, Ing. Leon Febres Cordero and it has 10 members: six of them represent the Municipality of Guayaquil, one member represents the United Nations, two members from Universidad Catolica de Santiago de Guayaquil and one member from GeoHazards International.

The Executive Committee has ordinarily met every two weeks, and extraordinarily every time the circumstances have demanded. More than forty sessions have been celebrated. The names of the members and affiliation are shown in Appendix 1.

3.5.2. The Work Groups

Many Work Groups were formed for the execution of the different activities of the project. The groups were formed by officers of the Office of Urban Development Plan of the Municipality of Guayaquil (DPLAN-G), the Department of Civic Promotion and Press, the Departments of Computer Engineering and Environmental Department of the Municipality of Guayaquil; and by specialists of the Research and Development Institute of

the School of Engineering (IIFIUC) of Universidad Catolica de Santiago de Guayaquil. The names of the members and their affiliation are presented in Appendix 2.

3.5.3. The Institutions that support RADIUS

The Mayor of Guayaquil, Ing. Leon Febres Cordero made a letter of summons addressed to more than 50 institutions which were eager to collaborate actively and with a high civic spirit, contributing information, checking the estimations of the damage diagnosis prepared for the "Earthquake Scenario", and contributing in the formulation of the "Action Plan" for the mitigation of seismic risk of Guayaquil.

3.6. INAUGURAL MEETING

The Municipality of Guayaquil officially inaugurated the RADIUS Project in the City Hall of the Municipal Palace on May 19, 1998. RADIUS stands for "Risk Assessment Tools for Diagnosis of Urban Areas Against Seismic Disaster".

The RADIUS Project is sponsored by the Secretary of the International Decade of Natural Disasters Reduction (IDNDR) of the United Nations, and it has been executed in nine selected cities after a rigorous selection process in which 59 cities from all over the World participated.

Program of the Inaugural Meeting

Figure 8. RADIUS Inaugural Meeting

Mr. Luis Chiriboga Parra, Vice-Mayor of Guayaquil (Center), and Mr. Víctor Aznar (Right), functionary of the Representative Office of the United Nations in Ecuador.

1. Welcoming speech by Mr. Luis Chiriboga Parra, Vice-Mayor of Guayaquil;
2. Conference: "The City at a glance", by Arq. Felipe Huerta (Municipality of Guayaquil);
3. Introduction to RADIUS Project, by Dr. Carlos Villacís, Co-Director;
4. Conference on the Historical Seismicity of the Country and the Region, by Ing. Hugo Yepes, Director of IGN;
5. Presentation of Objectives, Work Plan and Organization of the Project, by Ing. Jaime Argudo, Scientist Responsible for the Project;
6. Explanation of the Advisory Committee, by Dr. Carlos Villacís, (GeoHazards International);
7. Report on the Project progress, by Arq. Guillermo Arguello, Director of the Urban Development Plan of the Municipio.

Mr. Luis Chiriboga expressed his satisfaction in the selection of Guayaquil for the execution of the RADIUS Project, and declared that the Municipality of Guayaquil will support and collaborate decisively with the United Nations in this initiative directed to produce on a World level common tools for the reduction of seismic risk.

He said that the Municipality of Guayaquil has developed a new digital cartography for the entire city, and that important investments are being made to strengthen the urban planning of the city. He pointed out that in the last six years the Municipality of Guayaquil has improved significantly in this area, which makes it possible for the Municipal Government to contribute to such a world effort as that of the RADIUS Project.

Dr. Villacís highlighted the importance of the participation of the public and private institutions and NGO's in the different stages of the project, as well as the support required by the media to allow the results of the project to be presented to the community.

The Director of the Office of Urban Development Plan of the Municipality of Guayaquil (DPLAN-G), Arq. Guillermo Arguello, highlighted the progress of the project since its start on February 1, 1998. The information about the infrastructure and building stock of the city has been completed, and many theme maps have been developed about the different systems of basic services (water, electric power, etc.), and the urban equipment (hospitals, schools, etc.), together with the analysis of the seismic intensities expected for the different types of soil in the city.

CHAPTER 4: EVALUATION OF SEISMIC HAZARD AND SEISMIC RISK

4.1. PREPARATION AND DATA COLLECTION

4.1.1. Historical Seismicity

A historical research of seven earthquakes (1653, 1942, 1943, 1946, 1956, 1971 and 1980) whose effects on the city of Guayaquil correspond to an Intensity equal to or greater than VII in the Modified Mercalli Scale was carried out. The main sources of information were the historical chronicles and newspapers.

As a result of this research, a collection of maps have been prepared, which illustrate the zoning of the damage produced by the seven researched earthquakes in the so called "mixed" and reinforced concrete structures, as well as the inventory and pattern damage that have generally occurred to buildings, life lines and human life. (See figure 9)

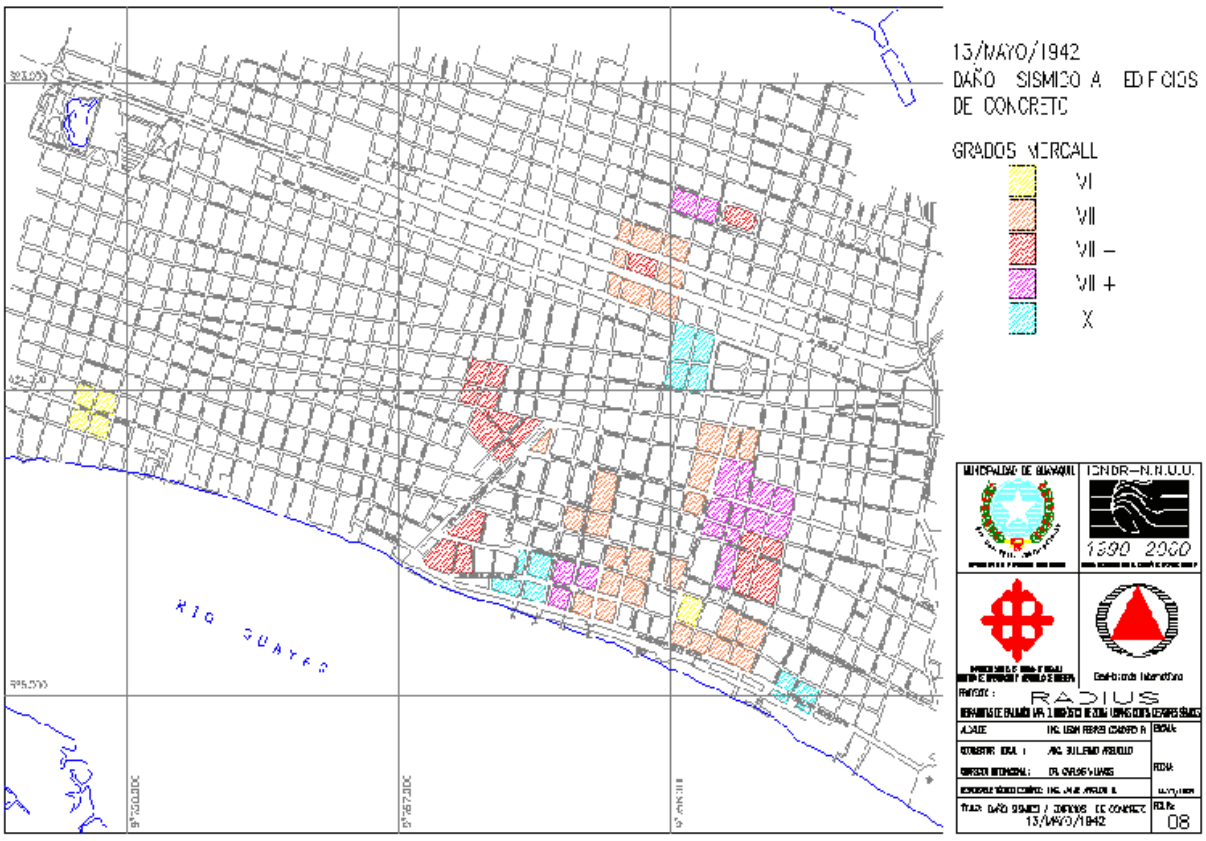


Figure 9. Geographical distribution of damage of the earthquake of May 13, 1942 in reinforced concrete structures. The largest Intensity was equal to IX, and the average Intensity is estimated to be VIII degrees.

Another information generated by this study is related to the urban history of the city, which has led to the understanding of how the unplanned urban development has helped to increase the seismic risk.

Figure 10, shows the places where old creeks were located within city limits; they were filled during the first years of this century. For some earthquakes, a relation between filled creeks and the increase of damage intensity has been established. This has always been the case for buildings located along Avenue Olmedo where the San Carlos creek use to be located.

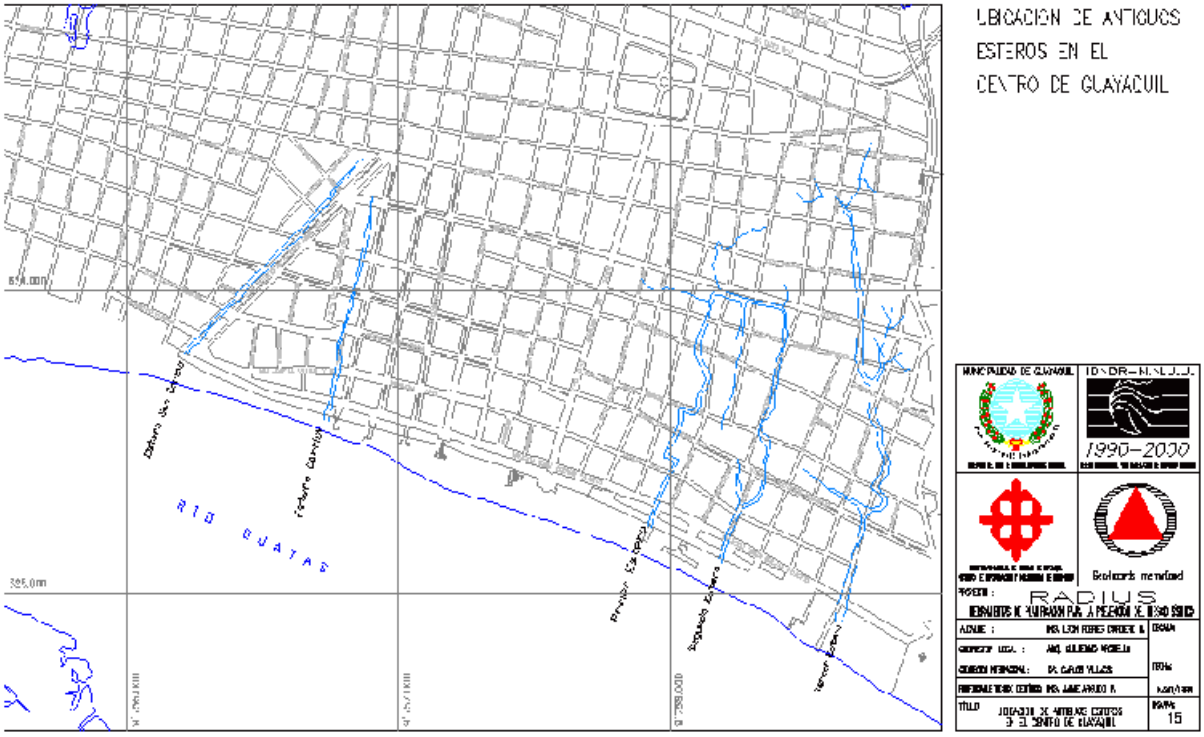


Figure 10. Location of old creeks of Guayaquil

4.1.2. Seismic Catalogues

The Seismic Catalogue for Ecuador describes seismic intensities (damage) and associated phenomenon (landslides, tsunamis, floods, etc) that have occurred since the year 1541. The information related to magnitude is available since the year 1901, but due to the different precision on the instrumentation in the first years of the XX century, the records of the period 1963 to 1998 are more reliable than those of the period 1901 to 1963 [6].

The data reported for the recorded intensities in the catalogues associated to an active seismic source is used for the analysis of the "Seismic Hazard" in order to estimate the probability of occurrence on a certain level of Intensity in Guayaquil.

In figure 11, the epicenter, magnitude, and intensity felt in Guayaquil for each of the earthquakes that have affected the city during the present century are presented.

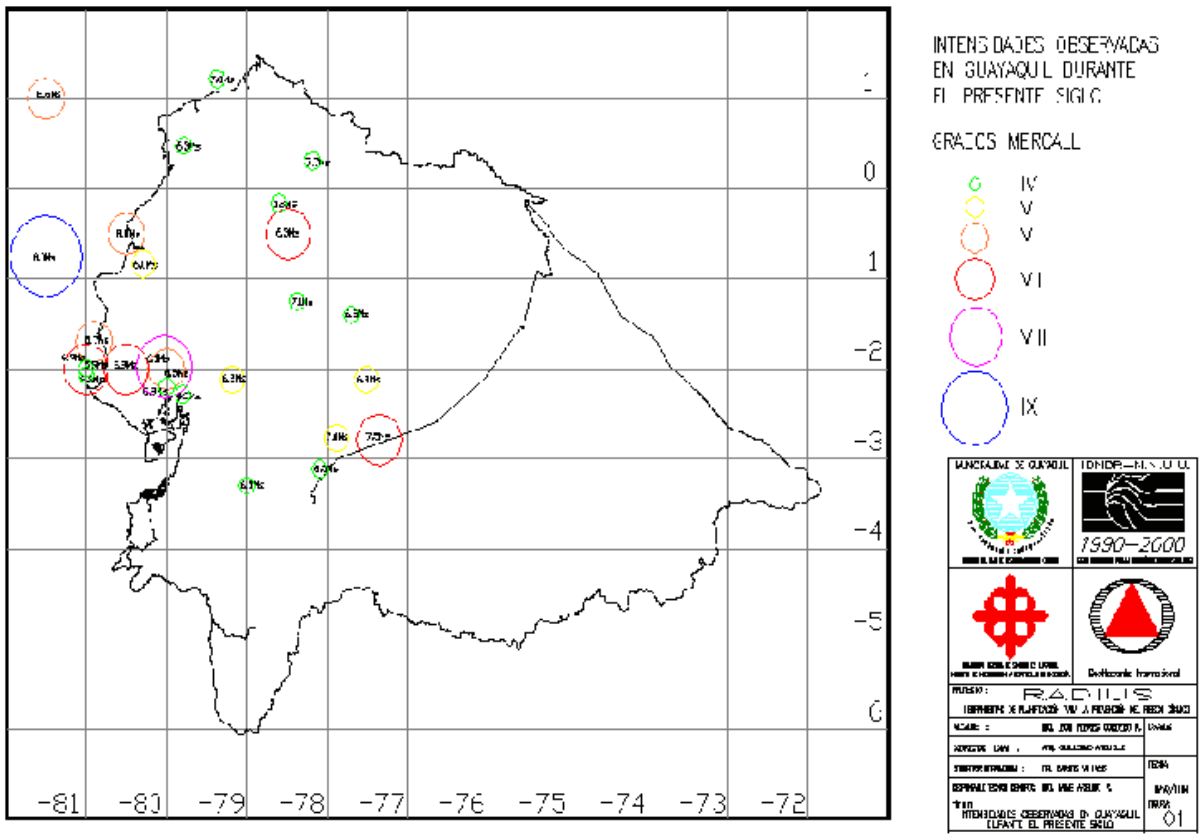


Figure 11. Location of the earthquakes felt in Guayaquil during the present century

4.1.3. Technical Reports

Although this type of information is scarce, it happens to be the most reliable for the zoning of seismic intensities in the city.

The earthquakes of May 1942 and January 1943 in Guayaquil were extensively described and studied by Dr. Arnaldo Rufilli, an Italian who was an structural engineer, builder and professor at Universidad de Guayaquil [15].

Other recent earthquakes like the one on August 1980 have been studied by municipal committees or governmental committees established for such purpose, or by private consulting engineers who have analyzed the damage suffered by buildings with the intention of repairing or strengthening them.

4.1.4. Acceleration records of soil

Accelerographs are instruments that measure and record the acceleration of the soil and this variable is related to the level of damage suffered by structures. Although isolated acceleration records prior to 1989 can be found, it is since this year that national networks of accelerographs exist in Ecuador. The networks are groups of instruments destined to cover a region or a city [12].

In Guayaquil a network of accelerographs installed by Universidad Catolica de Santiago de Guayaquil (IIFIUC) has made it possible to record the movement of the soil during the past decade. Five instruments located over soils of different characteristics have recorded 25 small earthquakes during that period of time.

The acceleration records of the network have been grouped according to the type of soil and are shown in figures 12, 13 and 14.

4.1.5. Preparation of cartographic data

The cartographic data available at the start of the project in digital format from the Municipality of Guayaquil, from IIFIUC and from other institutions, was not fit to be used by a GIS (Geographical Information System) that RADIUS Project has prepared using the ARCWIEW program.

A laborious work of digitizing, purging and migration of data had to be done for the cartographic data available in AutoCAD and MICROSTATION format to be used by the GIS of RADIUS.

The following maps with the infrastructure of lifelines and essential facilities prepared for the GIS (1:10,000 scale) are:

a) Main network of transportation and distribution of Potable Water in Guayaquil. (source: ECAPAG). The network of distribution of water using pipes serves to 77% of the city;
b) Main network of Sewage Water in Guayaquil (source: ECAPAG). It covers 50% of the city;
c) Network of Rain Water Sewers in Guayaquil (source: ECAPAG). It covers 50% of the city;
d) Network of Electric Power Transmission and Substations in Guayaquil (source: EMELEC) Coverage:100%;
e) Main network of roads and bridges in Guayaquil (source: Municipio of Guayaquil) Coverage: 100%;
f) Location of Fire Department Stations (source: Municipio of Guayaquil). Coverage less than 50%.

The following cartography was prepared under AutoCAD format for illustration purposes:

a) Geology of Guayaquil with the fault systems at 1:100.000 scale. (source: CODIGEM);
b) Seismic Zoning of Soils of Guayaquil (source: IIFIUC);

c) 15 theme maps with information about the infrastructure of basic services (life lines) and urban services (hospitals, schools, etc.) combined with the Seismic Zoning;
d) 4 maps showing the location of earthquakes felt in Guayaquil from different seismic sources with the seismic intensities reported from the catalogue (source: RADIUS);
e) 14 maps with the damage distribution produced by important earthquakes felt in Guayaquil during 1942, 1943,1971 and 1980 (source: RADIUS);
f) Location of old creeks in Guayaquil in the Center Zone (source: RADIUS);
g) Density of cadastral sectors of the commercial values of buildings (source: RADIUS);

4.1.6. Data base of structures: building stock

Two data bases of structures (building stock) have been used for different applications:

a) The cadastral data base of Municipality is based on the census of buildings made during the period of 1993 to 1996; it covers all the city and has data of over 300,000 buildings.

b) The data base of IIFIUC, was prepared on the basis of a census carried out between 1992 and 1993 by IIFIUC for many sectors of the North and Central Zone of the city. This data base has information of over 35.000 buildings and it covers 15% of the city.

The data base of the municipal cadastral was used for the damage estimation of the "Earthquake Scenario", and the IIFIUC data base was used for the identification of the vulnerability factors and inspection program carried out for the validation of the "Vulnerability Functions" used in the project.

In the initial stage, the municipal cadastral data base was consolidated to display the information of the risk variables for the 97 cadastral sectors on the city and the 64 groups of structures that were formed as a function of the materials used for their construction (concrete, wood, steel), type of walls (used to define if a building was just made out of wood or "mixed" with wood and bricks), the height, use and degree of conservation of the buildings.

Later, once the vulnerability functions were defined and the vulnerability factors were identified, the data base was consolidated again for the 97 cadastral sectors according to 12 types of well defined structures by means of grouping the former 64 types of structures, and keeping the necessary information for the simulation of the damage of each type and sector: number of buildings, cadastral value and area of construction.

The description of the type of buildings and a report of the number of structures within each group are presented in table 4.

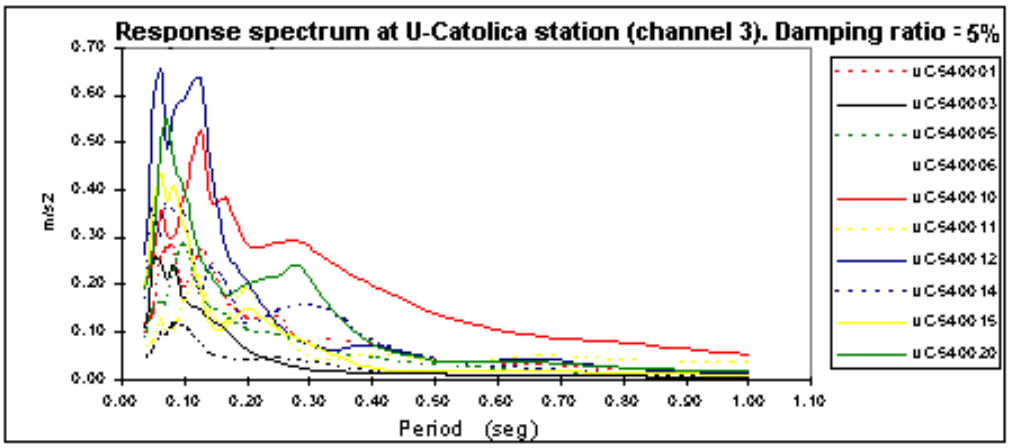


Figure 12. Response Spectra in soil Type I – Guayaquil

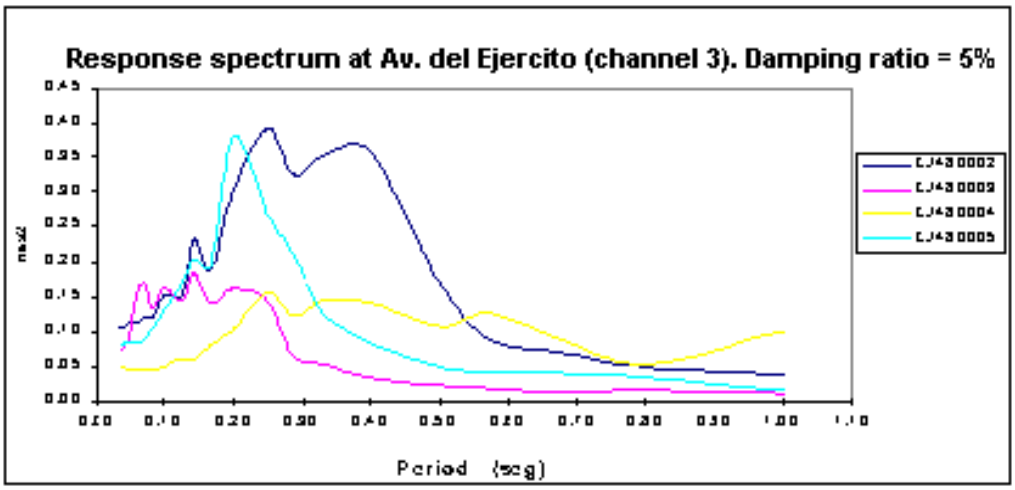


Figure 13. Response Spectra in soil Type II – Guayaquil

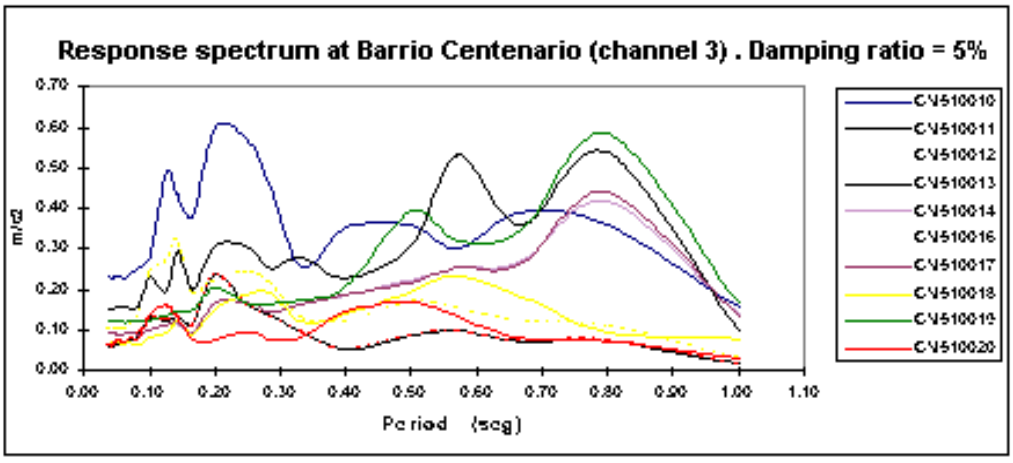


Figure 14. Response Spectra in soil Type III – Guayaquil

Table 4. Inventory of buildings from the cadastral base

TYPE	DESCRIPTION OF BUILDINGS	NUMBER
A	WOOD OR CANE HOUSES IN GOOD CONDITION	
	Wood houses of 1 or 2 levels, poor condition..... 61.280	
	Wood houses of 3 levels or more, good condition.....58	61.338
B	MIXED HOUSES IN GOOD CONDITION	
	Mixed houses of 1 or 2 levels. 13.353	
	Mixed houses of 3 or more levels 1.883	15.236
C	WOOD OR MIXED HOUSES OF 1 OR 2 LEVELS IN POOR CONDITION	
	Mixed houses of 1 or 2 levels, poor condition 1.276	
	Wood houses of 1 or 2 levels, poor condition.....6.079	7.355
D	WOOD OR MIXED BUILDINGS FROM 3 TO 6 LEVELS IN POOR CONDITION	
	Mixed buildings from 3 to 6 levels, poor condition.....218	
	Wood buildings from 3 to 6 levels, poor condition.....41	259
E	REINFORCED CONCRETE HOUSES OF 1 OR 2 LEVELS, RESIDENTIAL USE	
	Houses in good condition.....198.469	
	Houses in poor condition 873	199.342
F	REINFORCED CONCRETE HOUSES OF 1 OR 2 LEVELS, COMMERCIAL USE	
	Houses in good condition 9.286	
	Houses in poor condition 103	9.389
G	REINFORCED CONCRETE BUILDINGS FROM 3 TO 6 LEVELS, RESIDENTIAL	
	Buildings in good condition 8.882	
	Buildings in poor condition.....21	8.903
H	REINFORCED CONCRETE BUILDINGS FROM 3 TO 6 LEVELS, COMMERCIAL	
	Buildings in good condition.....2.482	
	Buildings in poor condition.....21	2.503
I	REINFORCED CONCRETE BUILDINGS FROM 7 TO 13 LEVELS	
	Buildings of commercial use.....174	
	Buildings of residential use.....50	224
J	REINFORCED CONCRETE BUILDINGS 14 LEVELS OR MORE	
	Buildings of commercial use.....13	
	Buildings of residential use.....8	22
K	STEEL STRUCTURES OF ONE LEVEL	
	Structures in good condition.....2.252	
	Structures in poor condition.....10	2.262
L	STEEL STRUCTURES OF TWO LEVELS OR MORE	
	Structures of commercial use.....102	
	Structures of residential use.....90	192

4.1.7. Investigation of a sample of critical buildings

RADIUS carried out a program of inspections to 191 buildings and an equal number of survey forms were prepared, an example of them is shown is figure 15. The inspections were used to:

a) Study vulnerability factors and their predominance in the different groups or types of structures;
b) Obtain information for the calibration of the vulnerability functions of Costa Rica [16] and the ATC-13 from USA [5], to define functions for building types C, D, G, H, I, J and L;
c) Make a diagnosis of the risk and estimate the damage percentage by means of the Damage Index Method;
d) Make recommendations to reduce the risk in these important or critical buildings.

There were 62 inspections to reinforced concrete buildings affected by past earthquakes, 85 inspections to wood or mixed houses in poor conditions, 40 reinforced concrete buildings of four or more levels and 4 steel buildings.

4.2. VULNERABILITY FUNCTIONS

4.2.1. Buildings

Based on a research upon the damage produced by historical earthquakes (including the earthquake of Bahía of August 4, 1998), an inspection program to investigate 191 buildings; and the study of vulnerability and damage function of other countries [5] – [16], the "Vulnerability Functions" or "Movement-Damage Relations" for the 12 types of buildings of Guayaquil were defined.

In Table 5, the damage percentages of the Vulnerability Functions are presented. The damage percentages are a relation between the reposition cost of the damage and the cost of the building. They express the average damage that each type of building would probably experience given a certain seismic intensity.

In Figures 16, 17 and 18, these functions are presented graphically, and they are compared with other functions for "Non reinforced masonry" and "Wood" from Costa Rica, and "Adobe" from Quito-Ecuador.

4.2.2. Lifeline facilities

For the damage estimation of lifeline facilities, the damage matrices proposed by the ATC-13 (Applied Technology Council, 1985) were used [5]. Applicable matrices were selected considering the factors that best reflected the conditions found in Guayaquil´s lifelines systems. These are shown in table 6.

R A D I U S
EVALUATION OF URBAN VULNERABILITY
RAPID VISUAL SURVEY

Direction 1: Joaquín Chiriboga
Direction 2: Av. Olmedo

1. General Information

Date: September 19, 1998
Name: Cámara de Comercio
Address: Av. Malecón y Joaquín Chiriboga

Group: reinforced concrete buildings affected by EQ's
Inspector: Ing. Jaime Guamán

Chamber of Commerce Building: Minor damage and partial destruction of walls during the 1980 EQ.

2. Type of building
☐ STEEL ■ CONCRETE ☐ MIXED ☐ WOOD

3. Use of building
☐ Residential ☐ Commercial ☐ Education
☐ Government ☐ Emergency ■ Other

4. Structural System
■ Frames c>v ☐ Flat slabs + columns ☐ Frames + walls
☐ Frames c<v ☐ Flat slabs + walls ☐ Other

5. Main dimensions
Number of levels = 6
Bays direction 1= 2.8 m ☐ Intermediate building ☐ Effect small building
Bays direction 2= 2.6 m ■ Corner building ☐ Effect large building

6. Quality of construction
■ Good ☐ Average ☐ Bad

7. Vertical Irregularity
■ None ☐ Small ☐ Large

8. Plan Irregularity
☐ None ☐ Small ■ Large

9. Soft Story
☐ None ☐ Upper levels ■ First floor

10. Pounding
■ None ☐ One side ☐ Two sides ☐ Three sides

11. Cantilever balconies
■ None ☐ One side ☐ Many sides

12. Observations: Very vulnerable to non structural type of damage (architectural and installations) estimated on the basis of 16% of damage cost of the building for the RADIUS scenario earthquake. The risk factors are its slenderness in the north-south direction, the smaller stiffness of the first floor and its irregular plan. In its favor is the good quality of construction, bays of small length and a lot of columns. The building should experience only small structural damage.

Figure 15. Example of a survey form prepared from the 191 inspections

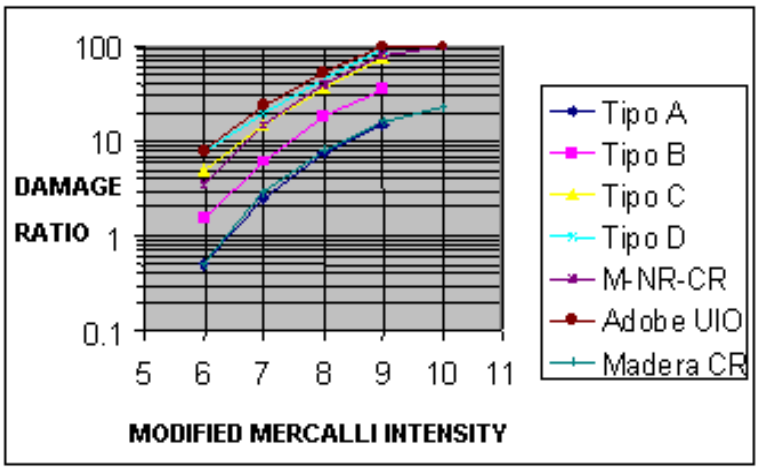


Figura 16. Vulnerability Functions for wooden and mixed structures (A, B, C, D)

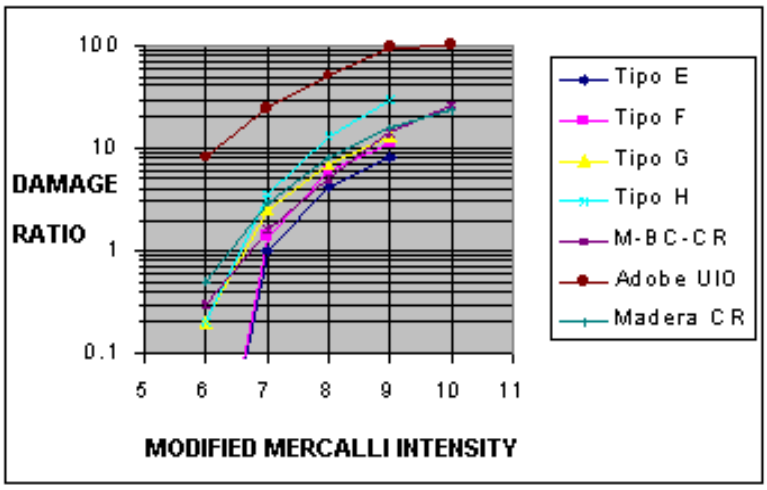


Figure 17. Vulnerability Functions for reinforced concrete buildings (E, F, G, H)

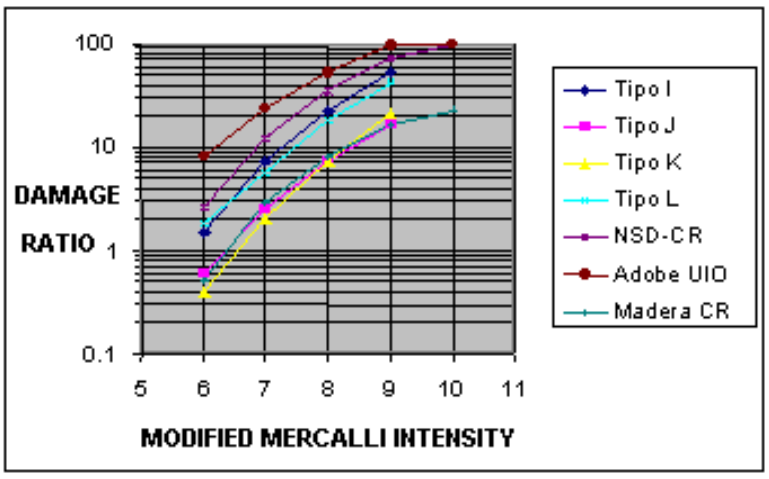


Figure 18. Vulnerability Functions for reinforced concrete (I, J) and steel buildings (K, L)

Table 5. Vulnerability Functions of buildings for Guayaquil

Type of Building	average damage (%) for the specified seismic intensity			
	I = VI	I = VII	I = VIII	I = IX
A	0.5	2.5	7.5	15
B	1.5	6	18	40
C	5	15	36	75
D	7.5	20	45	90
E	0.05	1	4.1	8
F	0.05	1.4	6	16
G	0.2	2.5	7	16
H	0.2	3.5	13	33
I	1.5	7	22	52
J	0.6	2.5	7	17
K	0.4	2	7	21
L	1.8	5.5	18	42

Table 6. ATC-13 Vulnerability Functions for lifeline facilities

Type of Lifeline Facilite	% of damage			
	I = VI	I = VII	I = VIII	I = IX
Water treatment plants	0.57	1.05	2.66	4.42
Water pumping stations	2.35	5.85	11.73	20.74
Water storage reservoirs	1.1	4.1	6.45	10.63
Trunk and distribution lines	0	0.69	1.56	5.21
Electrical substations	4.93	10.1	20.37	33.75
Distribution lines	0.03	1.39	2.62	4.71
Local roads	0.25	1.95	5.39	13.55
Bridges	0.49	4.35	9.37	27.23
Airport terminal	1.83	4.02	8.93	17.01
Airport runway/taxiway	0.01	0.41	4.87	10.76
Emergency services (fire & police stations)	2.8	5.1	14.43	22.0
Hospitals	2.22	4.94	10.04	19.35

4.3. ELEMENTS AT RISK

4.3.1. Vulnerability Factors of Buildings

The severity of damage depends upon many Vulnerability Factors which incidence and predominance have been studied by means of an inspection program and a research of the damage produced by historical earthquakes. The different Vulnerability Factors are described in the following paragraphs:

4.3.1.1. Aging and height of mixed buildings

The main variables that cause risk in mixed buildings are their age and poor condition, as well as their height, because seismic forces acting upon the structure are increased proportionally to the height of the structure. These buildings are predominant within type "D". In these houses the risk of life loss for the occupants and people walking by is a lot greater than any other type.

The geographical distribution of buildings type "D" is illustrated with the help of a GIS in map 4, in which the concentration of these buildings in the Central Zone of the city is seen. See figure 19.

4.3.1.2. Aging of mixed houses

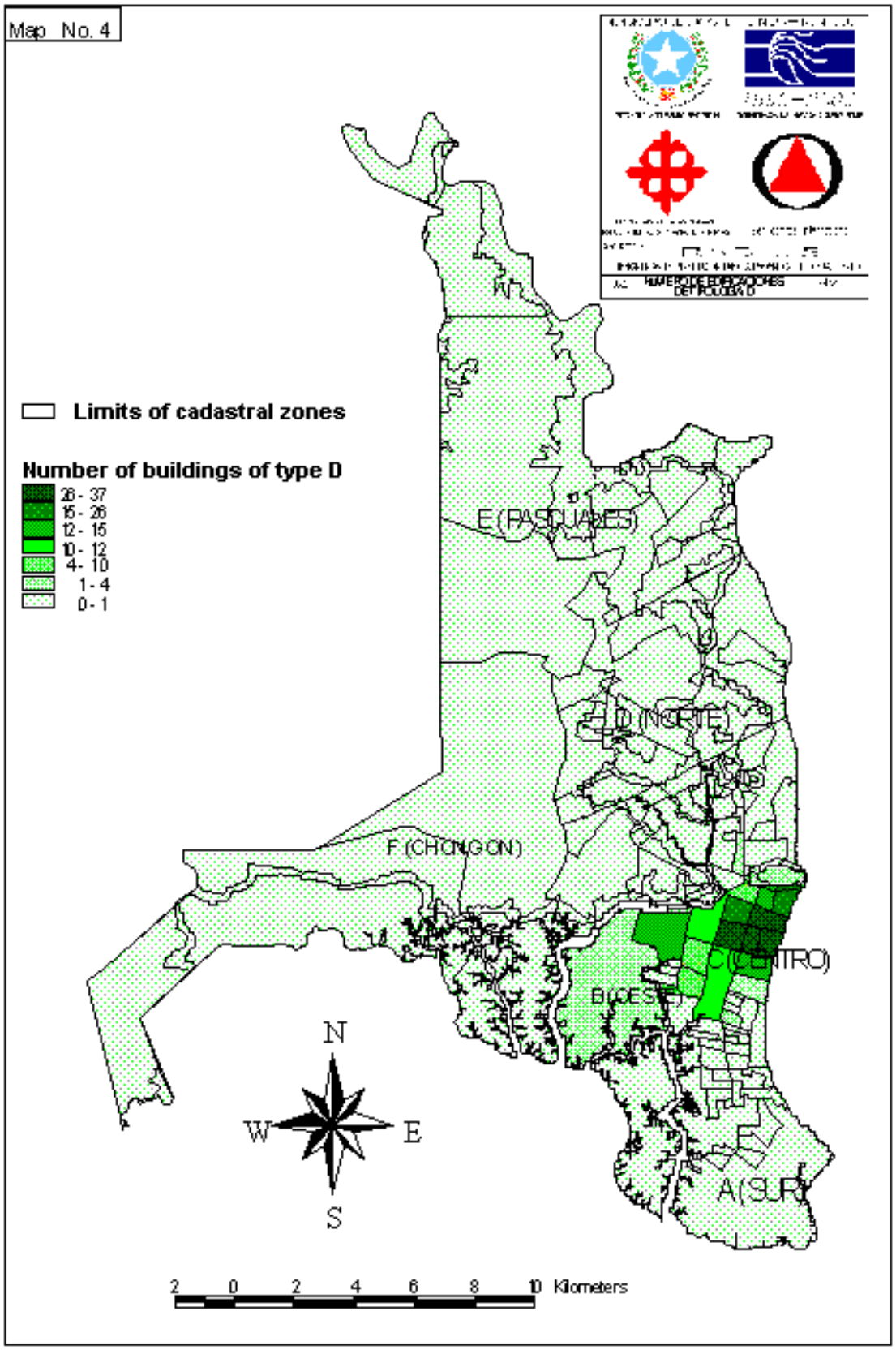
The majority of wooden houses are safe (type A) because they are very light in weight (made out of cane) or because they are relatively new and their materials are in good condition. A small group of wooden houses are very old, they have two and rarely three levels, and can withstand a larger damage than those of cane due to their age.

These buildings are predominant within type "C" and they have a similar seismic behavior to those of mixed structures of two levels due to their age. The fundamental difference between a wooden and a mixed structure in poor condition is in the larger probability of human life loss the latter has, due to the possible falling of heavy walls made out of clay bricks. See figure 20.

4.3.1.3. Weak Columns and Strong Beams in reinforced concrete buildings

This is a characteristic factor of buildings built without any seismic resistant code between the years 1939 and 1970. This condition is very critical for buildings of three or more levels, which in addition have other factors of risk such as a first soft story and are located in the corner of a city block. See figure 21.

Almost all the buildings of this type are located in the Central Zone, and because the construction of buildings of great height started in Guayaquil in the 1970's, almost all of them belong to buildings of types G, H and I. In map 5 the geographical distribution of buildings of type H is shown.



Map 4. Geographic distribution of mixed buildings in poor condition, 3 or more levels (type D).

Figure 19. Example of a mixed building of four levels in very poor condition, type D.

Figure 20. Example of a very old wooden house and in very poor condition, type C.

4.3.1.4. Soft first story

It is very common that reinforced buildings of three or more levels of commercial use (type H or I), have in their first story a condition known in structural engineering as "soft story". Due to architectural requirements, building have large open spaces in the first floor for using them as stores, warehouses or garages. Other buildings such as schools also require open spaces in the first floor for playing grounds.

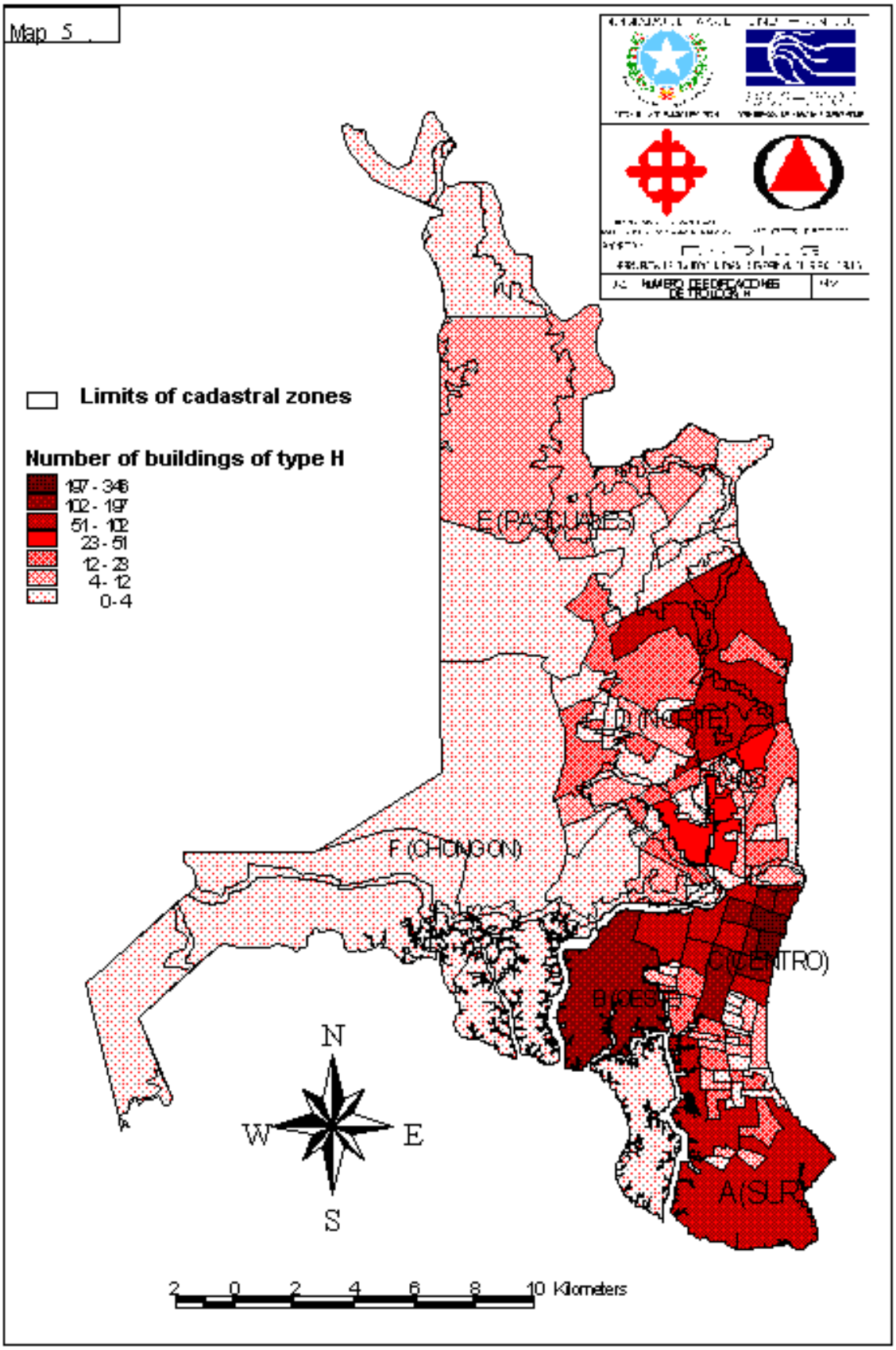
Additionally, in the Central Zone of the city, the municipal ordinances mandate that a minimum height of 4.5 meters for the forming of the traditional "portal" a king of porch in the first floor, which produces a mezzanine of smaller dimensions. See figure 22.

4.3.1.5. Excessive Slenderness

Excessive slenderness is often present in reinforced concrete buildings of 7 or more levels (type I and J). It is critical when the ratio of slenderness which relates the height of the building and the smaller dimension in plan is greater than 2. See figure 23.

4.3.1.6. Pounding or buildings too close together

The custom to build buildings very close to each other, specially when they are of different heights, produces harmful effects in the structures because they do no behave as they were designed to, and can cause mutual damage because of the impact (pounding) against each other. This factor is very common in buildings in the Central Zone. See figure 24.



Map 5. Geographic distribution of reinforced concrete buildings of 3 to 6 levels, commercial use (type H).

Figure 21. Reinforced concrete building, built between 1930 and 1970, which has many risk factors: weak columns, soft first story, and located at a corner. It belongs to type H.

Figure 22. Building with "portal" and mezzanine, defined as a soft first story. It belongs to type I.

Figure 23. Example of type I building, with a critical slenderness ratio.

Figure 24. Example of type I building, leaning against each other and with risk of impact.

4.3.1.7. Non structural factors and cantilever balconies of great length

The use of cantilever balconies of great length, glass window facades with fragile connections (curtain walls or "glass skin"), slender ornament elements, facade parapets, or any other heavy element without good fixing conditions constitute a risk to the life and security of people. See figure 25.

4.3.1.8. Complex Architecture

Buildings with architectural plans in the shape of L, T, H, U or I, have a poor seismic behavior with predominance of torsion, therefore they are more vulnerable to damage than those buildings with rectangular plans. Such situation also occurs when geometrical changes are done along the height of the building. See figure 26.

Figure 25. Building with "glass skin"

Figure 26. Building with irregular plan

4.3.1.9. Bad construction practice and construction without seismic codes

75% of local construction is not done with a rigorous application of a construction code or seismic regulations. Many buildings are built "informally", that is, without the supervision of a qualified professional engineer or architect (50%) and without the municipal control.

This situation is worse in buildings built with the greatest deficiencies (25%), and becomes very critical (5%) if the building has a height in excess of 2 or more levels (see figure 7). The seismic risk is therefore increased noticeably when bad construction practice occurs in buildings of type G, H, I, J or L.

4.3.1.10. Amplification of structural response

Almost all of the structures of type "I" have been built on soft soil in Guayaquil. Because the dynamic properties of the buildings are very similar to those of the soft soil (period of vibration), this "resonance" can amplify the intensity of damage. This has been taken into consideration in the formulation of its vulnerability function.

4.3.2. Essential and community services facilities at risk

4.3.2.1. Hospitals

It is estimated that 10% of the hospitals have a certain risk of suffering structural damage, which can be from total to partial collapse of the structure. 75% of them could be non operational after an earthquake of Intensity VIII [3] due to the following reasons:

a) Hospitals built without any special provisions for the control of excessive lateral deformations (drift), and without protection of vital functions among other important variables;
b) Some hospitals built near unstable ground or in places with complex access;
c) Great architectural complexity and some have very slender structures. (figure 25);
d) Some have large numbers of columns partially confined (short columns);
e) Construction defects or lack of maintenance on the seismic expansion joints;
f) Many of them are very old (aging) and do not have seismic resistant design;
g) Their lifelines are sensible and they have lack of proper maintenance and are usually deteriorated.

4.3.2.2. Fire Department Stations

The majority of the 22 Fire Department Stations of the city are located on very old buildings without any seismic resistant design, with weak columns and first soft story due to the need of open spaces for the fire engines. Some stations have experienced damage during past earthquakes and it is estimated that up to a 50% of them could be non operational after an earthquake, due to the effects of the earthquake on the structure of the stations buildings or because of lack of maintenance.

4.3.2.3. Schools

A total of 21 high schools and 34 elementary schools were affected after the earthquake of August 18, 1980, and were only able to reinitiate classes a week after the event. At that time there were nearly 800 school buildings in the city, today there are nearly 1,500 and it is estimated that 10% of them could suffer severe damage and in a few cases they could suffer partial or total collapse because of the following reasons:

a) Their first story is a lot more flexible than the upper levels;
b) Many structures are old and do no have seismic resistant design;
c) In some cases their architectural plan is complex.

4.3.2.4. Temples and Churches

The main factors that determine the high seismic risk of Temples and Churches are:

a) Age. The majority of them (Catholic churches) were built before 1940;
b) Their structures have elements of great flexibility, such as domes;
c) Abundance of ornament and decorative elements poorly fixed on the structure;
d) Lack of emergency exits; the few that exists generally have doors that open to the interior which make evacuation difficult and increase the risk of injuries in situations of panic.

4.3.3. Vulnerability of Lifelines

Damage in life lines produce a lot less fatalities than the damage in buildings. However, these damages have a great influence in the recovery process after a disaster and can cause great social discomfort if they are not prevented, controlled and rapidly taken care of. The most vulnerable vital system of the city in order of their importance and risk are: potable water, energy power and telephone communications.

4.3.3.1. Potable Water

The supply system for Guayaquil is very vulnerable to strong earthquakes, and the social impact of the damage caused would probably be very strong. This statement is based on the following:

a) The infrastructure of obtaining and producing water at "La Toma" Plant is strongly dependant on the energy power, which in turn is subjected to rationing due to possible damage to the National Interconnected System;
b) The four aqueducts are the most vulnerable component of the system due to the aging process, low redundancy (three of them follow the same route), deterioration because of clandestine connections and lack of devices for energy dissipation due to deformation (flexible joints) in the places where changes in the type of soil occur;
c) The storage or reservoir tanks are small with capacity to supply a few hours of water to the city, and a group of them are located in Santa Ana Hill, at the top of a slope prone to landslides [14];
d) The distribution water volume are very low in the Central, South and West Zones, where the greatest difficulty of water supply and distribution is expected in the case that an earthquake causes an important reduction in the capacity to transport potable water to the reservoir tanks.

4.3.3.2. Energy Power

The energy power system of Guayaquil is dependant on the National Interconnected System (NIS) and a major damage in it would reduce up to 50% the supply of energy to the city. The local network presents the following critical points:

a) The generation plants have very limited protection systems against fires;
b) The energy substations are sensible to damage to cables (power lines) and their insulators that may interrupt their operation for a few days;
c) Transmission and distribution lines are the most vulnerable, especially those across unstable slopes; also the cables make curves where the cable tension is eccentric or very close to old buildings which walls may collapse and bring down posts and cables.

4.3.3.3. The Telephone System

This system bases its vulnerability on the following items:

a) The "Central Centro", from where all national and International communications operate and where all critical installations are, is located in an old building without seismic design and with a background of damage in the earthquake of 1943;
b) The communications with the national network are transmitted from a tower on top of Santa Ana Hill and it is located over a slope prone to landslides [14];
c) The national and International communications is strongly dependant of the systems of other cities, mainly from Quito, Cuenca, Manta, Machala, Quevedo, Babahoyo and Galápagos.

4.4. EVALUATION OF THE SEISMIC HAZARD

4.4.1. Selection of the earthquake adopted for the Scenario

There are three sources in Ecuador that can generate earthquakes with an Intensity equal or greater than VII in Guayaquil [19]. The sources and their events with the largest reported intensity in the city are:

a) The North-Western coastal zone, it has produced 5 earthquakes with a magnitude larger than 7.0 Ms; the most important being in 1942 which produced an Intensity of VIII for Guayaquil;
b) The South-Eastern zone, it has generated 2 earthquakes with a magnitude equal or larger than 7.0 Ms; the most important being in 1971 which produced an Intensity of VII for Guayaquil; and,
c) The Local zone, it has produced three earthquakes with a magnitude between 6.0 and 7.0 Ms; the most important being in 1980 which produced an Intensity of VII for Guayaquil.

Using the information from the Seismic Catalogue (see section 4.1.2), in table 7 a summary of the seismic hazard that represents for Guayaquil each of the three sources is presented.

Table.7. "Seismic Hazard" from each seismic source area for Guayaquil

Seismic Source	Maximum magnitude expected	Probability of exceeding the max. Magnitude within the next 10 years	Return Period of maximum Magnitude	Intensity Observed	Return Period of the Observed Intensity
North-Western zone	8.0 Ms	14.0%	67 years	VIII	379*
South Eastern Zone	7.2 Ms	31.0%	28 years	VII	155*
Local Zone	6.5 Ms	13.0%	72 years	VII	159

* The return period of Intensities result very high for earthquakes from this zones. It is because before the XX century, Guayaquil was a city with low vulnerability, with light structures, low in height.

As a consequence of the previous analysis, we decided to select for the preparation of the "Seismic Scenario" of RADIUS a subduction earthquake generated in the North-Western coastal zone, with a Magnitude of 8.0 Ms and an epicenter located 200 Km. away from the city. This is an earthquake similar to the one of May 13, 1942.

The reasons to adopt this particular earthquake are the following:

a) With this type of earthquake we can simulate the occurrence of an Intensity of VIII degrees in Guayaquil. The other sources have not generated in the past earthquakes that have produced intensities larger than VII.
b) The frequency with which earthquakes of Magnitudes greater than 7.0 Ms is larger for this source. For example, an earthquake of magnitude 7.2 Ms has the annual probability of occurrence of 13.8% for the North-western coast, 3.6% for the South-eastern zone and there a no evidence for the local zone.

We do not discard the remote possibility that a local active fault may produce in the future an event with a magnitude larger than 7.0 Ms and with an Intensity equal or larger than VIII for Guayaquil due to the closeness of the source.

4.4.2. Intensity Distribution in Guayaquil for the adopted earthquake

The information described in sections 4.1.1, 4.1.3 and 4.1.4 and the studies described in section 4.4.1 have been used for the determination of the seismic intensity associated to each region or type of soil.

The proposal of reference [4], "Seismic Zoning of Guayaquil" was used for the definition of the three regions of the city where Intensities of VI, VII and VIII degrees are expected to occur. This zoning defines the borders of the three types of soils that the city has: Type I (rock or firm soil), Type II (intermediate or transition soil) and Type III (soft soil), and it classifies the soils according to their dynamic properties.

In map 6, the distribution of intensities expected in the city for an earthquake like the one adopted is shown; this was later used for the preparation of "Damage Seismic Scenario" of RADIUS Project.

4.4.3. Evaluation of collateral hazards

4.4.3.1. Fires

The most important collateral risk of an earthquake for Guayaquil is the fires that could be produced by it; the city has 67 gas stations and 18 energy power facilities that could become sources of fires, moreover the city has 85,000 wooden and mixed houses. At least one fourth of them have electrical installations in poor condition.

Some energy facilities do not have automated systems for fire control. In order to avoid big fires it is recommended that a special control of gas stations and energy facilities be located in the Central Zone, and also the construction of new fire stations in other zones where wood construction is predominant and the service provided by the Fire Department is inadequate.

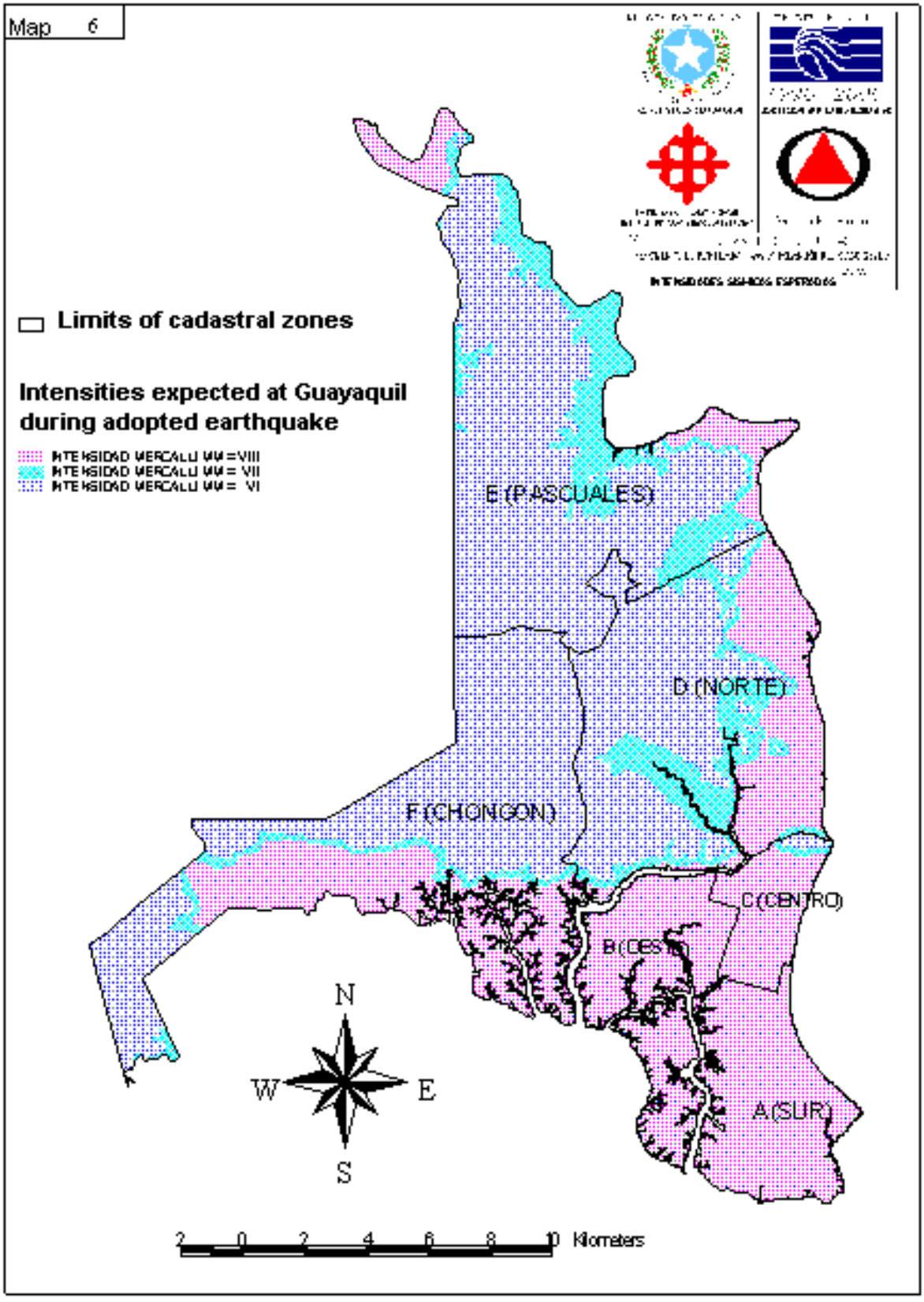
4.4.3.2. Landslides

Another collateral risk of earthquakes is the landslides that may occur in the hills to the north and west of the city.

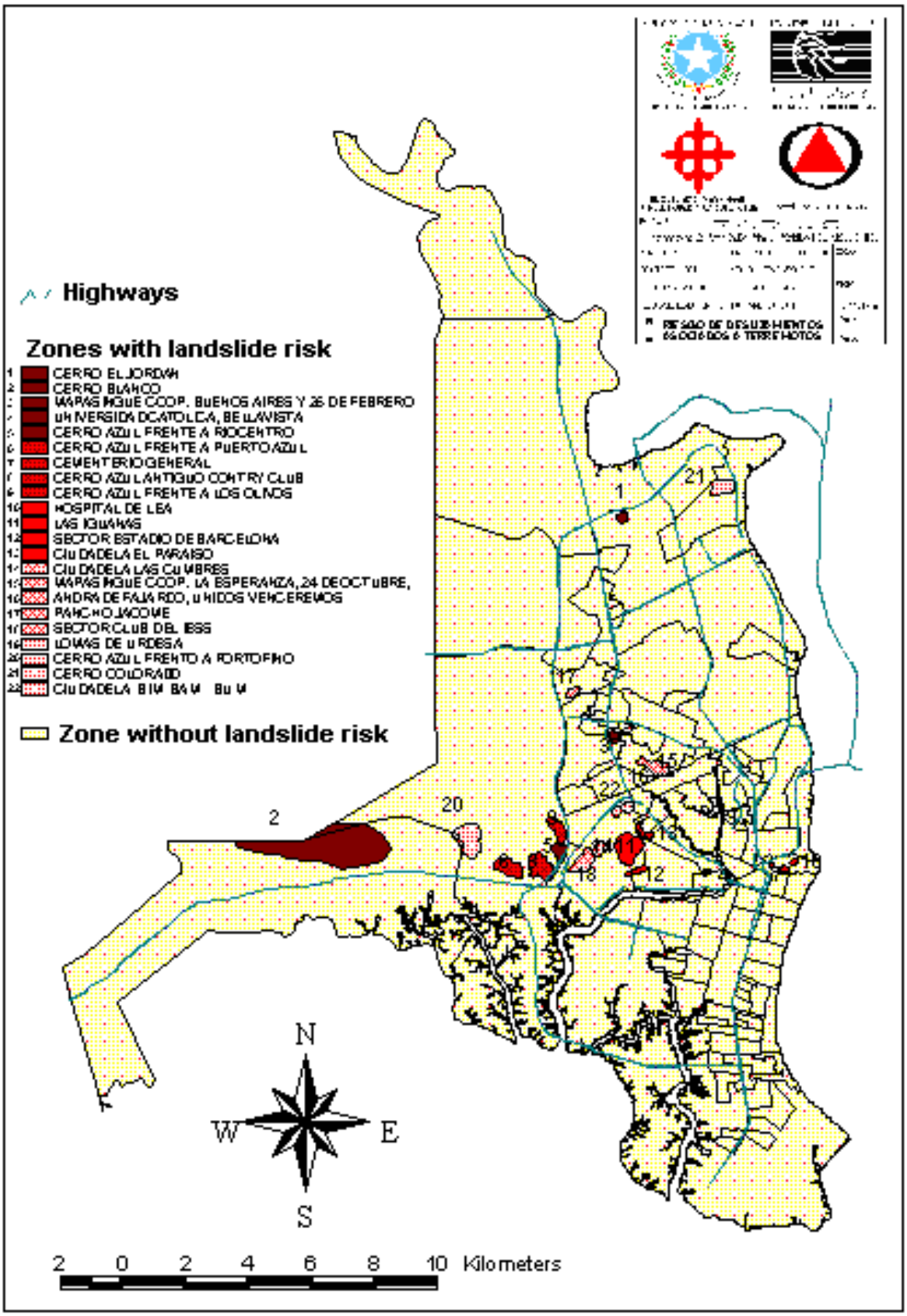
Due to the fact that the expected intensity in rock for the adopted earthquake is low, in order for landslides to be produced, there must be extreme conditions present: the susceptible hill slopes must be saturated with water, they must be formed by loose residual soils, they must belong to places where previous faults have been determined, and finally they must be in conditions of extreme instability.

With the previous hypothesis combined with the geologic information, a geomorphologic analysis following reference [18], the diagnosis of references [12] and [14], and site inspections carried out by RADIUS personnel, map 7 was prepared which identifies the zones susceptible to landslides as a collateral hazard of an earthquake.

Using a scale of colors in which the more intense or dark colors denote higher risk, the zones with the most vulnerability are shown: the slopes of hills Cerro Blanco, Cerro Azul, Bastión Popular, Ciudadela El Paraíso, Santa Ana and El Carmen, San Eduardo, Bellavista – Universidad Católica.



Map 6. Expected Intensities during the adopted earthquake for the Scenario



Map 7. Areas susceptible to landslides as a collateral hazard of the adopted earthquake

4.5. RESULTS FROM THE INTERVIEW PROCESS

4.5.1. Objectives fulfilled

4.5.1.1. Gathering Information

a) Identify special characteristics of the vital systems and how they function
b) Gather data to be used on the "Earthquake Scenario"

4.5.1.2. Studying the potential for mitigation

a) Evaluate the capacity and the response and recovery time
b) Identify the possible actions to be carried out for the reduction of the risk

4.5.1.3. Making the Public Aware

a) Inform about the Project
b) Educate and make people aware of the Seismic Risk

4.5.2. Institutions interviewed

The operators of twenty important institutions related to the provision of vital and essential services to the city in the case of an earthquake were interviewed [9]. These institutions were:

a) ECAPAG (County Company for Potable and Sewage Water of Guayaquil)
b) EMELEC (Power Company of Ecuador)
c) PACIFICTEL (Public Telephone Company)
d) CONSEJO PROVINCIAL (State Organization in charge of the Administration of the Mendoza Aviles Bridge)
e) UNDER SECRETARY OF PUBLIC WORKS (Regional Office of the Ministry of Public Works in charge of the Via Perimetral)
f) CIVIL AVIATION (State Organization in charge of the Administration of Simon Bolivar Airport)
g) PORT AUTHORITY OF GUAYAQUIL (State Organization in charge of the Administration of the Sea Port of Guayaquil)
h) MUNICIPIO DE GUAYAQUIL (Government of the City)
i) CIVIL DEFENSE (State Office in charge of the coordination of disaster management)
j) RED CROSS
k) NATIONAL POLICE
l) ARMED FORCES OF ECUADOR (FF.AA.)

m) FIRE DEPARTMENT
n) TRANSIT POLICE OF GUAYAS
o) CATHOLIC CHURCH
p) EDUCATION BOARD (Provincial Office of the Ministry of Education)
q) MIDUVI (Regional Office of the Ministry of Urban Development and Housing)
r) INNFA (Regional Office of the National Institute of Child and Family)
s) HEALTH DIRECTION (Provincial Office of the Ministry of Public Health)
t) HOSPITAL LORENZO PONCE (Psychiatrist Hospital of the Honorable Junta de Beneficencia, which has the capacity of an important support for hospitalization and shelter in case of an emergency)

4.5.3. Vulnerability Diagnosis, capacity of response and recovery

The information gathered during the interviews was useful for producing a diagnosis of the vulnerability and the capacity of response and recovery of the essential systems of the city in the case of an earthquake. The results are presented in tables 8 and 9.

Table 8. Vulnerability Diagnosis of vital systems of the City in the case of an earthquake

VITAL SYSTEM	VULNERABLE POINTS	SYSTEM DEPENDENCE	REDUNDANCY OF SYSTEM
Potable Water	a) Canaleta Parshall in New Plant (La Toma) b) Reservoir Tanks in Santa Ana Hill c) Aqueducts (diameter of 42" and 72") d) Networks of distribution in places of changes of soil type	a) Energy Power of EMELGUR b) Via Daule for transportation of goods	Regular
Sewage Water	a) Network of collectors in places of changes of soil type. Especially the Parsons System b) Secondary Network in Central and West Zones c) Main Collectors under bridges	a) Energy Power of EMELEC b) Petrocomercial (diesel)	Bad
Energy Power	a) Connection with the Interconnected National System b) Cables and isolators in substations c) Transmission and distribution networks in unstable soils or hillsides d) End Posts or in curved lines	a) Electro – Guayas b) Central Paute c) Petrocomercial (bunker)	Good
Telephone	a) Tower on Santa Ana Hill b) Installations at Central Centro c) National and International Service	a) Central in other cities b) EMELEC	Bad

Provincial Board of Civil Defense	a) Equipment deficit b) Installations at Cuartel Sur c) Deficit of financial resources, lack of leadership and political support	a) National Direction of Civil Defense b) Government	Bad
Provincial Board of the Red Cross	a) Main Building b) Equipment deficit, lack of ambulance drivers c) Lack of financial resources and lack of ambulances for Red Cross workers	a) International Help b) Red Cross c) Partners contribution	Regular
Fire Department	a) Rescue equipment deficit, fires due to combustibles and chemicals b) Deficit of stations, fire trucks and equipment for operations in heights c) Seismic safety of fire stations	a) ECAPAG b) EMELEC c) National Government	Good
Municipality of Guayaquil	a) Ornament figures of the palace b) Lack of codes and control deficit in seismic resistant construction in the city	a) EMELEC b) PACIFICTEL	Good
Armed Forces	a) Communications deficit b) Lack of coordination with civil organizations	a) Government	Very Good
National Police	a) Personnel deficit, lack of financial resources b) Deficit of vehicles and equipment	a) Government b) Petrocomercial	Bad
Transit Police	a) Deficit of emergency equipment b) Lack of coordination between institutions	a) Petrocomercial (gasoline)	Bad
Provincial Board of Education	a) Building (10% in risk) b) Transportation and personnel desertion c) Lack of financial resources	a) Ministry of Education b) DINACE	Good
INNFA	a) Building (75% in bad condition) b) Transportation and personnel desertion	a) Ministry of Education b) Community	Good
MIDUVI	a) Lack of financial and human resources b) Land for construction of houses for poor people not available	a) Ministry of Housing b) Municipio	Bad
Catholic Church	a) Temples in risk b) Deficit of human resources	a) Community	Bad
Health Sector	a) Deficit of: beds for hospitalization, hospitals and emergency services b) Buildings at risk (10% collapse risk and 75 % vulnerable to be non-operational after EQ.)	a) EMELEC b) Red Cross c) Roads for transportation	Bad

Table 9. Diagnosis of the response and recovery capacity after an earthquake

VITAL SYSTEM	RESPONSE TO EMERGENCIES	CAPACITY OF RECOVERY	TRAINING FOR EMERGENCIES	CONTINGENCY PLAN AVAILABILITY
Potable Water	Variable Hours – days	Slow Weeks	None	For war emergencies
Sewage system	Slow Days	Very Slow Months	None	None
Energy Power	Fast Minutes	Variable Days – weeks	Some	For war emergencies
Telephones	Normal Hours	Variable Days – Months	None	None
Civil Defense Provincial Board	Normal Hours	Slow Weeks	Some	General Directions to face disasters
Red Cross Provincial Board	Normal Hours	Slow Weeks	Good	Plan for earthquakes emergencies
Fire Department	Normal Hours	Slow Weeks	None	None
Municipio de Guayaquil	Normal Hours	Normal Days	None	None
Armed Forces	Fast Minutes	Normal Days	Good	For war emergencies
National Police	Normal Hours	Slow Weeks	Some	None
Traffic Police	Normal Hours	Slow Weeks	None	None
Education Board	Slow Days	Very Slow Months	Some	Basic Plan for earthquakes
INNFA	Slow Days	Slow Weeks	None	None
MIDUVI	Very Slow Weeks	Very Slow Months	None	None
Catholic Church	Normal Hours	Very Slow Months	None	None
Health Sector	Fast Minutes	Very Slow Months	None	None

4.6. THE WORKSHOP ON THE EARTHQUAKE SCENARIO

The Workshop on the RADIUS Seismic Scenario took place from 20 to 22 January, 1999, with the participation of 70 representatives of 40 institutions.

The participants were gathered to carry out four tasks:

a) Review preliminary estimations of the damage caused by the adopted earthquake;
b) Describe the effects of the damage in their institutions;
c) Recommend projects for an ACTION PLAN destined to reduce the effects of an earthquake;
d) Suggest how to implement the ACTION PLAN

Figure 27. Some of the participants to the Workshop on the Earthquake Scenario for RADIUS.

During "Task A", the technical staff of Universidad Catolica and GeoHazards International presented the audience the studies carried out on the seismic risk of Guayaquil, the diagnosis of the vulnerability of vital systems of the city, and the estimations of the scenario of damage and losses caused by a probable earthquake to hit the city.

During the presentation of these results, the organizers and participants expressed their opinions. The suggestions about how to refine the results of the diagnosis and also the commitment on the need to assume future commitments for the implementation of the Action Plan of RADIUS were made. Following are quotations from two of the speeches:

"Two years ago, a simulation of earthquake disaster was carried out at the Civic Center, with the participation of all local and provincial authorities and representatives of Public Institutions. The result was to corroborate the knowledge that were are not even remotely prepared to face a disaster. That is why it is very important to think that we are assuming a responsibility for our City ....." Lcda. Gloria Gallardo (Director or Civic Promotion, Press and Publicity of Municipio de Guayaquil – Member of Executive Committee of RADIUS).

"In Guayaquil there are only three general hospitals that continuously work to full capacity. In the case of an emergency only 50% of the patients could be evacuated. Adding to the deficit of operation rooms, the damage of the earthquake and the traffic jams, hospital personnel will be six hours late to their working places, as it just happened in Mexico City, and the capacity of hospital beds will be reduced to a mere 10%. This is scary, I do not even think what would happen to our City in the case of an earthquake, because we do not even have trained personnel for emergencies as they do in other countries" Dr. Gustavo Soria (IESS hospital).

In order to carry out Tasks B, C and D, five working groups were formed with the following organizations:

Group 1: Basic organisms for emergency management
National Police
Army - II Military Zone.
Fire Department
Civil Defense
Red Cross
Traffic Police of Guayas
Media

Group 2: Life Lines
ECAPAG
EMELEC
PACIFICTEL
Under Secretary of Public Works
Direction of Civil Aviation
Airport Simon Bolivar
FAE (II Air Zone)
Port Authority
INOCAR
Thermoelectric Unit Guayas
Ecuadorian Committee of Geological Sciences

Group 3: (Welfare - Shelters)
Under Secretary of Education
MIDUVI
Church
INNFA
Civil Defense
DISPLASEDE, Direction of Education

Group 4: (Health Sector)
Direction of Health
Under Secretary of Health
Hospitals – Junta de Beneficencia
Civil Defense
IESS

Group 5: (Private Sector - Others)
FISE
Professional Architects
Chamber of Insurance Companies
SECAP
Universidad Católica de Guayaquil
Universidad de Guayaquil

The participants assumed with great responsibility the tasks and gave valuable opinions for the estimation of the impact of an earthquake and the definition of actions to reduce the risks. In total, 90 ideas of projects were suggested to be implemented in the short and long term, grouped within the following lines of action:

a) Evaluation and strengthening of buildings and dangerous infrastructure;
b) Training of personnel from basic organizations of citizen protection;
c) Forming groups specialized in rescues and emergencies, paramedics;
d) Within the Municipal Departments, the forming of a new Unit for Disaster Reduction was recommended;
e) Preparation of the community by means of prevention and mitigation campaigns;
f) Planning of the rapid response and restoration of services and life lines;
g) Preparation of emergency plans;
h) Control , acquisition, rehabilitation, modernization and maintenance of equipment of vital systems;
i) Study and monitoring of geologic and seismic risks, and;
j) Evaluation of urban areas, control of soil use, issuing a construction code.

4.7 THE EARTHQUAKE SCENARIO

Information for the preparation of the Earthquake Scenario was found in: sections 4.1 and 4.2, Elements at Risk and Seismic Hazard studies presented in sections 4.3 and 4.4 respectively, and the results of the Interview Process explained in section 4.5.

4.7.1 Economic losses in the building cadaster

The direct economic losses are obtained combining the distribution of intensities from map 6 with the damage percentages from table 5, and the building stock and its commercial value. The total amount of direct losses for the whole city in present market value is close to US $ 200 millions dollars. The geographic distribution of the calculated losses for each cadastral sector is illustrated in map 8.

The total losses are roughly estimated at US $ 1,000 millions dollars, after adding to the amount of direct losses, the losses of building equipment, and indirect losses caused by the temporary of definitive closing of services affected by the damage.

Finally, combining the losses with the Seismic Hazard we can estimate the "Seismic Risk", concluding that there exists a probability of 53% that the economic losses calculated for this seismic scenario be fulfilled in the next 50 years.

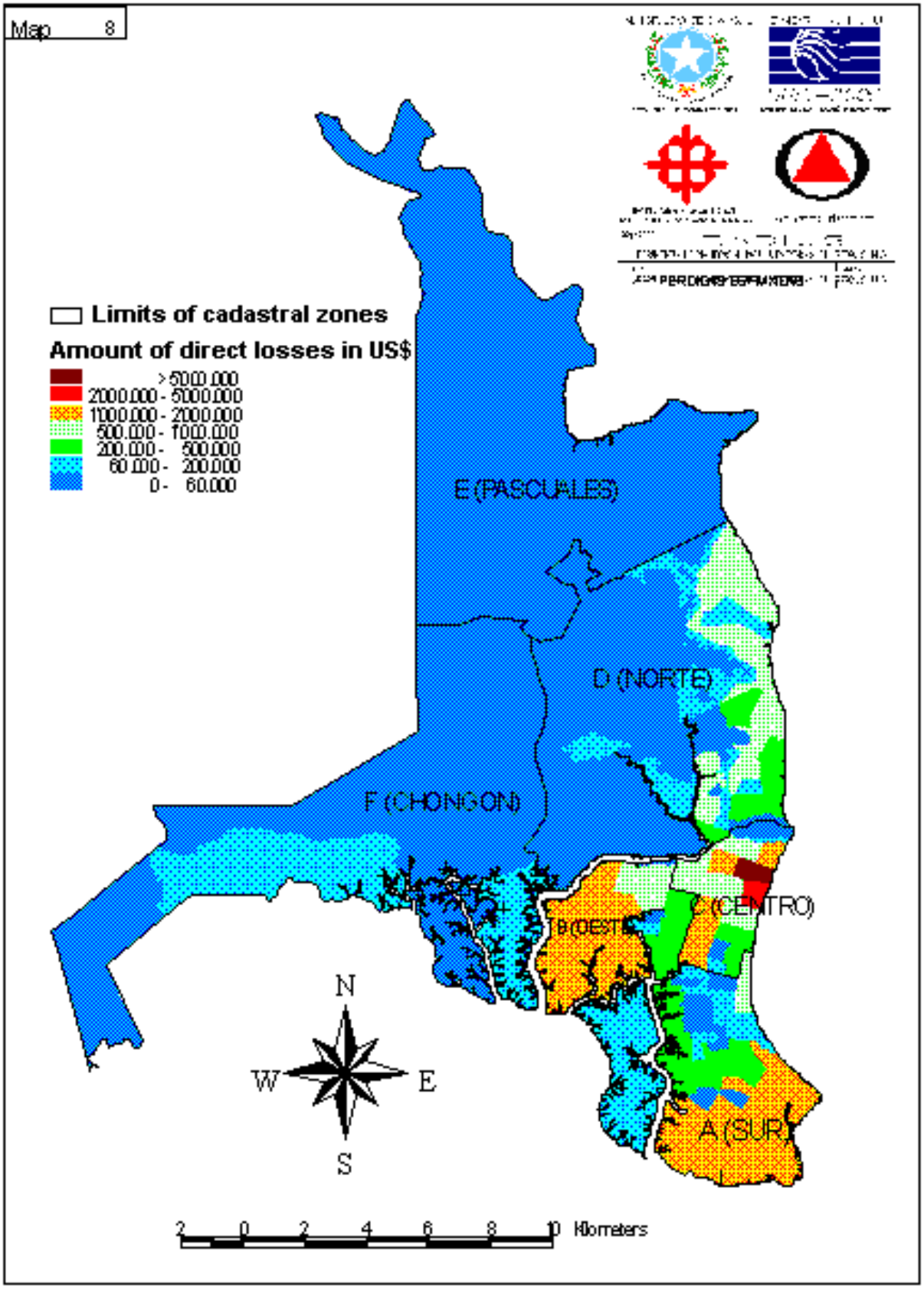
From the results obtained we can establish a qualification of the different zones of the City as a function of their risk:

a) The risk is very low in the zones of Pascuales and Chongón, because of the light density and small commercial value of buildings, and due to the predominance of better quality soils, except those soils located at the foot of the southern tip of the Chongón–Colonche mountain range;

b) The risk is low in the North zone because of the better quality of construction and a regular density of buildings;

c) The risk is moderate in the South and West zones because of the average quality of construction and the high density of buildings;

d) The risk is high in the Central zone due to the large number of mixed old houses and reinforced concrete buildings without seismic resistant design, high density of construction and large commercial value of buildings.



Map 8. Amount of direct losses by sectors, as a function of cadastral values

4.7.2 Damage to life lines and essential facilities

The intensity of damage in the vital systems and essential facilities for the city is obtained by the combination of the intensity distribution of map 6 with the damage percentages of ATC-13 shown in table 6 and the inventory of facilities. The results of the damage simulation are shown in table 10.

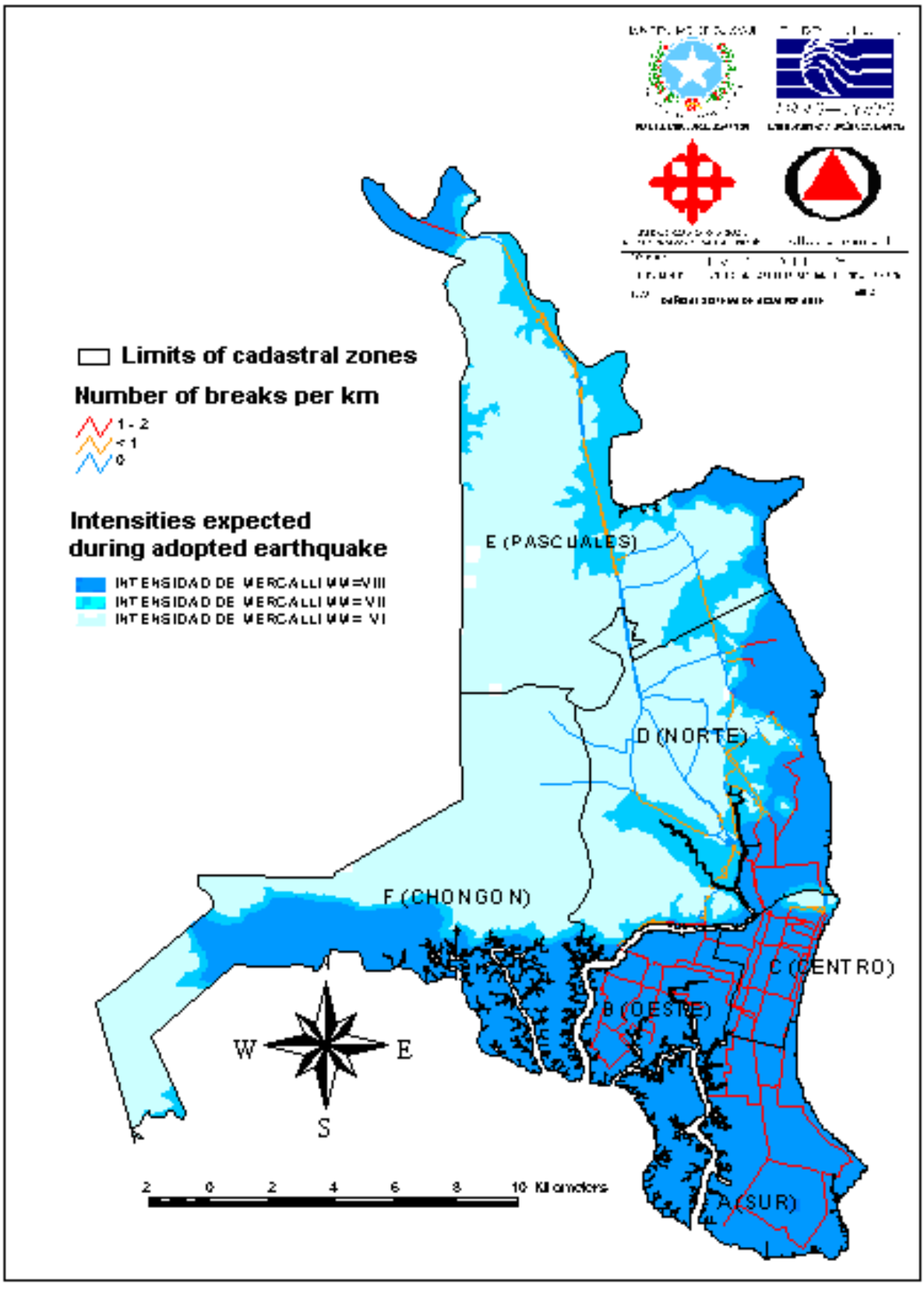
The results obtained must not be interpreted as a prediction of the damage caused by an earthquake, but as an estimation of the probable damage based on statistical methods for past earthquakes and the criteria of experts from the United States.

The results of table 10 are mainly used for the preparation and planning of the response and recovery of the city after an earthquake. Its correct interpretation is made in the following example of the case of bridges:

It is probable that the amount of economic losses will be equal to the cost of reposition of the 7,4% of the 61 bridges in the city (4,5/61). Because a smaller fraction of the 50% of the total amount of loses generally concentrates in a few structures (the most vulnerable ones), it is probable that in the region with an Intensity of VIII, 1 or 2 bridges may experience severe damage that force to the temporary closing of traffic.

Table 10. Damage estimation to life lines and essential facilities using ATC-13.

Type of Infrastructure	Units	Damage in the region of the city with the specified intensity		
		I = VI	I = VII	I = VIII
Potable Water Treatment Plants	%	1.09	-	-
Pump Stations of Potable Water	%	2.35	-	-
Reservoir Tanks of Potable Water	%	1.1	-	-
Main pipes (D > 400 mm.) of the transportation and distribution system of Potable Water	Number of breaks (NB)	0	42	173
Main pipes of Sewage Water	NB	0	29	245
Pipes of Rain Walter	NB	0	50	498
Power Substations	Substations	0.6	1	5.7
Transmission Network of power	Km.	0.02	0.58	2.12
Network of main roads of 4 lanes	Km.	0.15	0.72	4.37
Bridges	Bridges	0	0.6	3.9
Airport Passenger Terminal	%	-	-	8.93
Airport landing road	%	-	-	4.87
Fire Department Stations	Stations	0	0.1	2.9



Map 9. Probable damage to main networks of transportation and distribution of Potable Water for Guayaquil.

The following maps have been prepared with the aid of the GIS. An example is shown in map 9 for the trunk and main distribution lines of the water supply system of Guayaquil

a) Main network of transportation and distribution of Potable Water
b) Main network of Sewage Water System
c) Network of Rain Water System
d) Network of Power Transmission
e) Power Substations
f) Main Road Network
g) Bridges
h) Fire Department Stations

4.7.3. Estimation of deaths, injuries and homeless

Using factors that depend upon the damage percentage that each type of buildings experience and the population density, the number of people estimated to die is 22,461 and estimated to be injured is 90,114. See map 10.

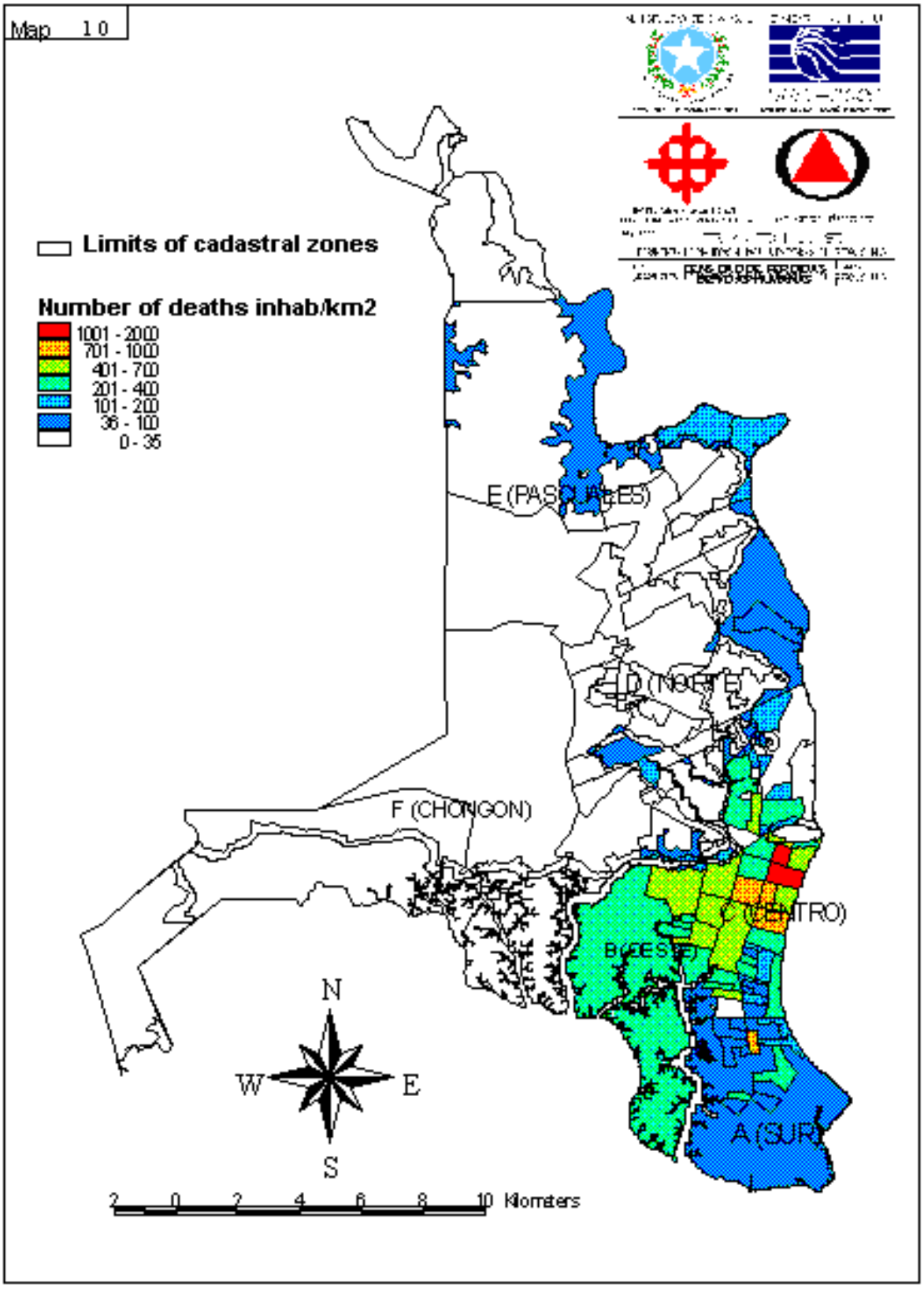
By the same token, the number of people without homes is estimated on the basis of the expected damage in buildings which has been calculated as 100,000 persons. The statistics of the number of deaths caused by earthquakes of Intensity VIII in cities with a population similar to the one of Guayaquil, varies from 10,000 up to 80,000 inhabitants.

4.7.4. The recovery of the city

In table 11, the projections for the time of rehabilitation of life lines on the city are presented. These projections are based upon the information gathered in 4.5 and are not predictions of any kind. They constitute useful information to give support to the planning and recovery of the city after a seismic disaster.

Table 11: Rehabilitation of vital services after an earthquake of Intensity VIII.

Type of Vital Service	Time necessary for the rehabilitation of damage		
	30% of damage	60% of damage	100% of damage
Power	2 – 3 days	1 week	1 month
Potable Water	1 week	1 months	2 - 3 month
Telephone	1 – 2 days	1 week	1 month
Sewage	2 weeks	2 – 3 months	6 months–1 year or more
Roads	1 week	2-3 weeks	1 – 2 months



Map 10: Distribution of the number of deaths

4.7.5. The Earthquake Scenario for Guayaquil in journalistic terms

This is an exercise of the simulation of the effects of the adopted earthquake for RADIUS. Its main purpose is to give information that helps in the planning and preparation of the city to mitigate the effects of a seismic disaster. This information can not be considered as a seismic prediction, as the only type of earthquake, or disaster scenario that may happen to Guayaquil.

4.7.5.1. The earthquake strikes

The time is 08h45 am of May 5, you have just arrived to your office located on the 10th floor of a downtown building in Guayaquil. Suddenly everything starts to shake, at first very slowly and then very fast. The windows and doors creak, the furniture is moving and you have great difficulty keeping your balance. To the shout of "EARTHQUAKE!" some of your office mates search for protection under the desks, and others run away terrified and staggering to the elevators. Somebody asks: "where are the stairs?".

Slowly, the movement begins to diminish, while the sound of buildings collapsing is heard. In 2 to 3 minutes the movement has stopped, but you think it was like hours.

4.7.5.2. Minutes later

You are on the street, somewhat beaten by the crowd that was coming down the stairs in a hurry. You hear the screaming of people from inside the buildings, there is no energy power in the buildings or telephone service. There are people running around looking for a safe place among broken glass and debris, and others are helping dead and injured people hit by the impact of fallen brick walls.

To the distance you can see clouds of dust hanging over other affected areas. You try to call up your family using your cellular phone but the telephones are not working, and you can not call up the firemen to rescue the people that are trapped in the elevators.

4.7.5.3. One hour later

You are driving your car and trying to get out of downtown by Malecón Simon Bolivar which looks open. However, the traffic has virtually come to a standstill. You wish to go to your children's' school in Samborondon County because you want to know what happened to them. Some people passing by warn you that you can not go through Loja Street because there is a tremendous traffic jam around Hospital Vernaza. You turn on the radio and listen to the news:

"A preliminary report from Instituto Geofísico Nacional says that the earthquake registered at a Magnitude 8.1 Ms measured on the Richter Scale, its epicenter was located to the north-west of Guayaquil and it was felt all

over Ecuador. Reports of considerable damage have been filed from the coastal cities of Esmeraldas, Bahía de Caráquez, Manta, Chone, Portoviejo and Guayaquil.

"The larger damage has occurred in the downtown area where many old houses of mixed construction type have collapsed partially or totally in some cases, stopping traffic to circulate from north to south along the following streets: Lorenzo de Garaycoa, 6 de Marzo, Pedro Moncayo and Jose de Antepara, and from east to west in Velez and Ayacucho streets. Almost 50 reinforced concrete buildings have collapsed, specially those located at corners of commercial use, there are many people dead or trapped at stores; there is a lot of damage and chaos at the majority of hospitals, some schools and many public buildings.

A landslide has cut off traffic on the Via Perimetral near Los Parques Urbanization caused by the slopes that were very wet due to the heavy rain that fell the week before the earthquake; another landslide has occurred in the slopes of Bim Bam Bum Urbanization, collapsing the back of the building where INNFA functions and there is a report that says many children are trapped in a day care center."

A report from ECAPAG says that there are many ruptures on three of the four aqueducts that transport potable water from Plant La Toma to Guayaquil: the pipeline of 42 inches which is the oldest of the system, the one of 72 inches and the one of 2,000 mm. Due to the damage occurred, the water supply is being restricted to the industrial sector and the South, West and Central zones of the city.

Fire is engulfing many houses of the city. Nearby 10 fires have been reported. The most critical is that of a mixed house of 3 levels located besides a gas station, the fire is threatening to extend to a large sector. Firemen had difficulties in getting there due to lack of personnel, traffic jams and fire trucks that were damaged by the collapse of walls and the structure of three old fire stations. The main Fire Department Station, located on Nueve de Octubre Avenue suffered cracking on the walls and falling of ornaments, and the destruction of the fire alarm service. The fight to extinguish fires still continues due to lack of water and hydrants in the city.

There is information that the whole city remains without power. Some substations, generation plants and transformers were damaged due to large variations of voltage. The Interconnected National System was also non operational due to over charges on the system.

The collapse of buildings in the Central Zone tore down high tension cables and pulled down most of the public light system which strength was reduced due to improper installations. Power lines were down and caused the majority of fires, and the electrocution of people. The falling of walls also pulled down telephone lines and left many zones without communication.

The city is isolated from the rest of the country and from other countries. Damage is reported in the Central Centro of Pacifictel; local telephone communication is jammed and is not working at all in the Central Zone.

One piece of news calms you, it is said that the north zone of the city has had no damage; you imagine that your spouse will be getting home located in that zone without any trouble. Another news anguishes you: it is confirmed that there is no traffic flowing through the Rafael Mendoza Bridge towards Samborondon; the Traffic Police are using wrecking cranes to move vehicles that lost control during the earthquake and collided against each other, including a truck that capsized on one side. A line of cars of many kilometers in length has formed. You wonder, how are my children?

4.7.5.4. Hours Later

After many turns to try to find empty streets you finally arrive home in Ciudadela Kennedy and find the neighborhood out in the streets fearing aftershocks may come soon. Standing on the doorways of their home some people are commenting on the dreadful moments lived a few hours before, the last reports of the radio, and the return of their relatives. At your home, some objects have fallen down on the floor and are broken: ornaments from the living room table, a wall clock, a picture frame and a shelf of books; some dishes that were on the kitchen table and a lamp beside your bed. The house has energy power because you live nearby Kennedy hospital which has not suffered the power rationing affecting the majority of the city. You receive the message that your children are safe at your brother's house who lives at the other side of the bridge.

On the streets of Clemente Ballen, Rumichaca, Ayacucho and Quito Avenue the chaos is worse. Many mixed buildings where whorehouses, saloons, tenement houses and warehouses used to function and upon which a municipal demolition order was pending, are now lying on the floor as rubble. Traffic policemen are trying to direct traffic to the south towards streets free of obstacles. The houses of wood and cane that are predominant on the marginal settlements of Trinitaria Island have resisted the major impact of the earthquake better than other zones and are still standing, although their occupants remain outside for fear of aftershocks.

Frightened by the strong movement, the inhabitants of the hills at Mapasingue and Ciudadela Los Ceibos, Lomas de Urdesa and Bellavista tried to find shelter at their own homes. Although some furniture moved, some objects fell down, and a few persons were injured there is no grave damage that may affect the stability of their houses. At Carmen and Santa Ana Hills some walls of the houses suffered cracks because the soil subsided where the hillsides have a steep slope.

At Ciudadela Urdesa, Sauces, Alborada y Martha de Roldós, the earthquake was strongly felt and the weak walls of some houses were severely cracked. The IX Stage of Sauces suffered a lot of damage because the houses were built without any seismic code and they had additional floors placed on top of them without the supervision of professionals.

The sewage water is inundating the streets around the Central, Ayacucho and Pedro Pablo Gomez Markets, and they are contaminating the fruits and vegetables that fell down on the floor. Pipelines coming down from the hills were also broken and flooded with putrid waters a large part of Urdesa Norte and Avenue Juan Tanca

Marengo. Pipelines that were buried under big fills to the west of the city suffered isolated ruptures and the flood gates of the pumping stations at La Chala and El Guasmo were opened due to the slight damage on their equipment.

Drivers are using Via Daule as an alternate route and it is now packed with many lines of cars trying to move among trucks and public transportation buses coming from other cities that have been deviated due to the closing of the Rafael Mendoza Bridge.

4.7.5.5. That afternoon

All television channels are transmitting live and are mobilizing news teams to the affected zones. One of the teams is at the Central Zone and is gathering testimony of survivals of the tragedy who are desperately looking for relatives with the help of neighbors on the debris of the collapsed houses. Some people say there are corpses trapped under the heavy masonry walls and furniture.

The Red Cross is asking people to donate blood, to prevent the blood supply of the city from running empty after a few hours. The donation campaign is taking place at the hospitals of Junta de Beneficencia de Guayaquil who are the leaders of the emergency because the Blood Bank and public hospital facilities were severely affected by the earthquake.

Some people with tears on their faces are telling stories about how they managed to save their lives, others are asking for the help of rescue organizations, medical attention and shelters that are not coming to the affected areas. There is still no news on where those people who have lost their homes may go to get refuge and shelter, or even those whose houses are in bad condition. The media is trying to tell people to go the schools but some of the schools are refusing to accept the people because of there is no any official order to do so. The people interviewed are also complaining because thieves are taking advantage of the situation to rob houses and businesses.

It is thought that the majority of the personnel of the Civil Defense, Fire Department, Red Cross, Traffic Police and National Police are attending to their own family emergencies or checking on their own houses. The personnel of these institutions currently at work is not capable of attending to the demands for help of the people. The Armed Forces has been mobilized to control the city and to collaborate in the rescue tasks, taking injured people to hospitals and corpses to the morgue.

The city is suffering from a blackout, power has been missing for nearly 6 hours and according to the latest news, is still suffering a power rationing that limits its activities in 80%. From the heliport of Luis Vernaza Hospital, the largest capacity hospital in Guayaquil, a television news team is reporting the intense activity registered at this health center, full of injured people, patients with traumatisms and nervous break downs. The radio advises citizens about the streets that are free of traffic and are being used to get quickly to the hospitals.

There is information that the water stored at the reservoirs of Tres Cerritos, Suburbio Oeste and the Santa Ana Hill has consumed, and ECAPAG is asking people to collaborate in order to protect the water stored at the cisterns on every house. The total absence of water could last two or three days while the damage to the aqueducts and collapsed pipe lines at the foothills of Carmen Hill, Bellavista and Tres Cerritos is totally repaired.

Meanwhile, workers from ECAPAG are planning the distribution of potable water by means of tank trucks because it is not possible to operate the reservoirs due to the loss of water through the openings in the main pipes. The people are complaining because the lack of water affects those poor families that do no have cisterns, causing people to wander around the neighborhoods looking for places to fill up their empty bottles.

The Simon Bolivar airport is going to be closed for at least 24 hours as a safety measure, limiting their operations to military helicopters only. The landing strip was lightly cracked after the earthquake, the passenger terminal has suffered damage that is being evaluated, as it is informed by the Civil Aviation Board.

On the contrary, the facilities of the Port Authority have not stopped their activities. There are no damage reports on the premises of the institution, which have adequate safety measures including those that limit the piling up of containers to prevent their turning up, as well as to keep the water reservoir full to protect themselves from an emergency situation.

Due to the closing of the Rafael Mendoza Bridge the Navy has authorized that the water transportation extends their usual routes. The passenger boats come from Duran, land on the wharf at Pedregal at Malecón Simon Bolivar, and continue to the wharf at Multicomercio on the South Market, and from there to the wharf at Terminal Terrestre in order to transport people that were isolated. Many people died due to the collapse of Terminal Terrestre building.

4.7.5.6. At night

The news says that traffic through the Mendoza Aviles Bridge is flowing slowly but the delays will last for a few more hours. At nightfall you are still listening to the news and are worried for your relatives; you have not been able to communicate with some of them because your telephone lines are interrupted.

The City is virtually dark because Empresa Electrica suffered the largest impact of the power rationing coming from the Interconnected National System. At present, 20% of the power being generated is destined to the sectors where hospitals and clinics are located.

On a live radio and television transmission the President of Ecuador has decreed a “State of Emergency” in the province of Guayas and orders the sending of help and technical personnel to make a preliminary evaluation of the damages and losses, he mobilizes the National Army and he organizes an Emergency Committee at the

Provincial Government in charge of the Civil Defense Board. He also instructs the people about the selection of some school buildings to be used as temporary shelters and the installation of tents by the Army at Universidad de Guayaquil, the parking lot of Modelo Stadium and other chosen sites.

On the corner of Olmedo and Boyaca Avenues, the building of IESS has partially collapsed. Workers and people who were early at those premises were trapped beneath the rubble. This institution will not be able to attend to those people due to the severe damage suffered by the structure of the building. Other reports on television show the old building where ECAPAG functioned and the Justice Palace in front of Parque Centenario to be in very bad condition.

It is feared for the fate suffered by the people who took refuge in the Victoria Church and the Basilica Menor Church which were hit by adjacent buildings and suffered collapse which affected one half of the structure. There was also a severe impact to the Cathedral and the following Churches: San Francisco, San Jose and San Alejo, where it is informed that the earthquake left many people hurt and injured among the parishioners attending mass.

On the neighborhoods to the south and west, many people are ready to spend the night and sleep out of their homes and do not go to shelters for fear that their houses may be vandalized or robbed. They have improvised the use of tents on their own means at the front of their homes, while others will sleep inside their vehicles and a handful will go to their neighbors or relatives that have offered temporary shelter. Their houses have cracks on the walls and they fear they will collapse with the aftershocks.

Once the traffic jam on the Rafael Mendoza Bridge in under control, the access to Samborondon is clear and your spouse has finally brought your children home.

4.7.5.7. The day after

With a great graphic display, the newspapers on the following day inform about the effects of the disaster, the situation of the people affected and the rescue tasks and removal of debris to take place in the city.

One of the interviewed experts says that the majority of affected buildings are located in the Central Zone and that they were founded on top of the soils where the intensity of the earthquake was the largest, and that they had other characteristics that made them the most vulnerable to earthquakes such as aging and lack of a seismic resistant design. The majority of the buildings which suffered total collapse are mixed houses in bad conditions and also the largest number of deaths took place in those buildings. The most important losses have been produced on reinforced concrete buildings of 7 levels or more, due to the damage to their installations and equipment.

The reinforced concrete buildings with structural damage are generally those located on the corners of the blocks, they have between 3 to 8 levels, shallow foundation, great slenderness, structural weakness on their first level and large cantilever balconies; they were not able to resist the seismic movement. Many of these collapsed buildings had been previously damaged during the earthquakes of 1942 and 1980 and they were built between the years 1930 and 1970 when the construction using reinforced concrete was not designed using seismic codes.

Some warehouses located to the south of the city and along Via Daule have stopped their industrial or commercial activity. These buildings had walls made out of unconfined clay bricks within metal structures; these walls collapsed causing severe damage to equipment and installations.

The Ministry of Education has suspended attendance to all schools. Some school buildings were severely affected, two school buildings collapsed and many children died. All school building will be subjected to a structural revision before ordering their opening. A preliminary list says that there were a lot of damages to the following schools: Ariel, 25 de Julio, Edmundo Lopez Dominguez, Republica del Ecuador and San Jose. There were also problems on the installations affecting the following schools: La Providencia, Santa María Gorety, Benjamin Carrion, Adolfo Simmonds, Guayaquil and Vicente Rocafuerte. Pupils and teachers that are members of the "Program for the participation of students in the Civil Defense System" are helping in the rescue tasks, evacuation of people and first aid help at their own schools.

A dramatic rescue takes place at the building of the Ministry of Agriculture and Cattle where employees of that institution and workers of the Under Secretary of Education and the Pan American Health Organization spent the night trapped on the elevators and were rescued after 24 hours of an anguish wait. One piece of news says that the Municipio de Guayaquil will coordinate the removal of debris with the help of the Direction of Public Works which will mobilize heavy machinery from their own and from private contractors to clear the streets closed to traffic. The work will be carried out with the collaboration of the machinery of the Army Corp of Engineers available at Batallon del Suburbio. The Provincial Counsel of Guayas will join this task, as well as the Under Secretary of Public Works.

The Provincial Government of Guayas is leading the coordination of the institutions that are supposed to respond to the emergency. It is evident that the Civil Defense lacks rescue equipment although it does have a large number of volunteers, specially students that are actively collaborating in the organization of shelters and the attention to the people affected with the coordination of INNFA. The Red Cross is also short of ambulances, stretchers, drivers and vehicles to mobilize the rescuers and the people injured.

With the help of the citizens other institutions such as Port Authority, Civil Aviation, and Armed Forces are collaborating with equipment and trained personnel. The Fire Department finally controls three fires that grew in size because of the lack of rapid intervention, combusting of chemical substances and which left many houses burned and people dead.

The Under Secretary of Health informs that their hospitals had so much damage that they had to be evacuated. These facilities experienced breaking of equipment, falling of false ceilings, window glasses, and brick walls that injured patients, doctors and hospital staff alike. Their vital services (sterilization, oxygen, power) are not working at all.

The situation is critical at the following hospitals: Solca, Francisco De Icaza Bustamante, Abel Gilbert, Military Hospital and IESS, where the damage to installations and equipment is very large, and for the fear of the aftershocks the patients have been evacuated and relocated in tents on the outside of the buildings. The very ill patients were relocated to private clinics because the hospitals Luis Vernaza, Maternidad del Guasmo and Lorenzo Ponce can not receive any more patients or people injured coming from other hospitals.

People injured coming from the central, south and west of the City have saturated Hospital Luis Vernaza. The staff of doctors and nurses are very tired because they have been working without stopping since the day before. The administrators of the hospital decide to release patients with minor injuries to give priority to critical cases. In spite of the efforts, it is impossible to attend to the demand.

The Under Secretary of Health, seeing the deficit of hospital attention, informs that with the aid of Junta de Beneficencia de Guayaquil, the Lorenzo Ponce hospital has received 500 new beds which proved to be insufficient. The Army has also contributed with the installation of first aid tents at their headquarters and other places of the City in order to give support to the crisis that the health sector is facing.

In the Central Zone of Guayaquil the business and commercial activities have virtually stopped: banks, stores, restaurants and small businesses remain closed. There is no public transportation with the exception of some taxis that operate only where the streets are clear of debris. The traffic lights are turned off due to lack of power and small traffic jams are sometimes formed, also many collision of cars and buses take place making people angry and desperate; this situation reveals the lack of preparation of the Traffic Police to face this kind of emergency situations.

4.7.5.8. Three days later

The water cisterns on the houses are empty in the south, west and central zones of the city. The Police are controlling the distribution of water by means of tank trucks, giving preference to hospitals and clinics. There is discomfort among the people because of the severe rationing of the water and the abuse by part of the distributors who are charging an excessive price to give the vital liquid.

It is a Monday after a very agitated weekend, you decide as usual to go to your work place. There you find out that a holiday of one week has been decreed by the government. Then a small movement of the soil makes you panic. It is only an aftershock but you have the impression that it is very strong and the earthquake can happen again. People are in anguish, walkers by try to look for protection under the porches of the buildings in a hurry.

The number of victims is growing due to the death of the gravely injured people and persons who did not get proper medical attention on time. The Police Morgue is full of bodies, many of them are unidentified. There are a lot of people desperately looking for missing relatives, forming lines outside the Morgue waiting for their turn to enter. The Anfiteatro Julián Coronel is also full of corpses and the administrators do not know where to put the bodies. The Civil Defense asks the owners of refrigerated cars to collaborate with the disposition of corpses.

An evident shortage of gasoline is present because the earthquake affected the Substation Pascuales which provided gasoline to distributors. Long lines of cars are formed trying to get whatever is left on the reservoirs of the gas stations; people denounce the speculation that there is and restricted selling of the product. Petrocomercial is announcing that it is taken the necessary steps to restore the service as soon as possible.

4.7.5.9. A week later

After a week the equipment from the Municipio de Guayaquil, the Armed Forces and the Under Secretary of Public Works are still removing the debris and retrieving corpses from the collapsed buildings. A preliminary report from the Civil Defense estimates the earthquake caused at least 20,000 deaths, 100,000 people injured and US $ 200 millions of dollars in direct losses. The public transportation system is returning to normal routine slowly. A good number of streets are now clean of debris.

Back to work, you notice that the commercial and banking activity is partially returning to normality. A good part of the essential services have been reestablished, but businesses have problems in working properly. At the banks the system is shut down frequently due to computer difficulties. The lack of money irritates the clients who are trying to withdraw their savings for emergency expenses. Technicians from ECAPAG have rehabilitated the aqueducts and main broken pipe lines and have restored the service to the industrial zone. The distribution of water from the reservoirs is also restored but there is still rationing and low water volumes due to important leakage of the pipe lines.

With the reposition of fallen light posts and high tension cables, the Empresa Electrica is restoring the service to the neighborhoods that remained in the dark. It is estimated that the Company has recuperated 60% of the energy it generates. Hospitals are still giving priority when rationing where any deficiency is covered by using gasoline portable generator plants. The Interconnected National Service is back to normal but they are rationing on a national level because some damage has been reported in some plants and substations of the system, particularly in Esmeraldas and Portoviejo.

The donation of food and medicine from friendly countries is still arriving by airplanes. The Simon Bolivar airport has fully reestablished its operations after being closed for 72 hours. However, the delivery of help to the affected people is very slow.

The Municipio of Guayaquil has ordered the complete demolition of the IESS building. A great amount of business transactions such as loans and money withdrawals are stopped at IESS creating difficulties for the clients who need money for emergencies. The authorities have not notified when or how the transactions are going to be restored.

4.7.5.10. A month later

The removal of debris from the affected buildings is still being done after a full month of the earthquake. The streets are completely clear of debris but there are debris on empty lots waiting to be removed. The Municipio de Guayaquil has ordered the demolition of nearly one thousand buildings that are in extremely bad condition and have suffered a lot of damage, their structures have been identified as not apt to be habitable. Many owners of buildings are looking at the possibility of repairing the structures as an alternative to the ordered demolitions.

After the inspection of the school buildings affected by the earthquake was completed, the Ministry of Education ordered classes to start again on those buildings that met safety conditions two weeks after the event. The rest of the schools (close to 100 buildings) will have their operation being postponed indefinitely. Parents fear that their children may lose one school year because of that decision.

The direct and indirect losses are estimated around US $ 1,000 millions dollars. Some businesses have difficulties recovering and are on the brink of filing for bankruptcy; Insurance Companies do not have the necessary amount of money to pay the policies and are offering advance payments while the damage is being evaluated.

The population is trying to adapt to the very difficult new conditions of life, because there is no money to repair the houses and buildings or to buy new things lost in the earthquake; there are still some deficiencies on the basic services although the power is almost fully restored and the commercial activity is completely normal by now.

Tents and shelters are still the only refuge for a lot of people who lost almost everything. In these temporary dwellings people are organizing to prepare food in common tins and pans and to fulfill cleaning chores. There are still more than 10,000 people living in these conditions. The government does not have the necessary resources to begin the reconstruction task, there is no bank credit that can make it possible to repair or reposition the destroyed buildings. International aid is expected to come to the rescue, such as Foundations and International Organizations to give priority to the strengthening and repairing of the destroyed hospitals.

The MIDUVI collaborates with the Municipio de Guayaquil in the process of recovery of the City; there are non government organizations (NGO's) which are planning and promoting emergency housing projects for the people affected by the earthquake, but these projects may take months or even years to become a reality.

CHAPTER 5: PLAN FOR THE MANAGEMENT OF THE SEISMIC RISK OF GUAYAQUIL

5.1. OBJECTIVES OF THE PLAN

5.1.1. General Objective

The main objective of the "Plan for the Management of the Seismic Risk of Guayaquil" is to avoid the loss of lives and to mitigate the social impact of an earthquake that may occur in the future.

In order to fulfill this general objective, some specific long term actions are proposed which aim: to diminish the intensity of the damage to buildings and economic losses, to regulate the new urban development with low seismic vulnerability, to strengthen the knowledge and education of natural hazards, and to introduce within the community a culture of the prevention and mitigation of the risks as a fundamental tool for their preparation of face disasters.

This plan is composed by the sum of some specific objectives, goals and activities that must be fulfilled in the city in order to mitigate the effects of earthquakes. Its main instrument is the "Action Plan for the Reduction of the Seismic Risk of Guayaquil", which was prepared with the participation of the representatives of more than fifty institutions of the city. It has concrete actions of specific projects that the institutions made the commitment to execute for the effective reduction of the risk.

5.1.2. Specific Objectives of the Plan for the Management of the Seismic Risk

The specific objectives of the Plan are:

1. Institutionalize a sustained process of the reduction of the risk in Guayaquil;
2. Strengthen the response capacity of the basic organizations of the city facing seismic emergencies;
3. Plan for health care and the social assistance during and after the disaster;
4. Plan for the recovery of the vital services and productive activities of the city after an earthquake;
5. Improve the seismic safety of buildings and infrastructure of the vital services;
6. Improve and renew the existing urban cadaster in conditions of low risk;
7. Regulate the seismic resistant construction of the new buildings and infrastructure and the safety against fire;
8. Strengthen the knowledge of the local seismic activity, their effects and techniques to mitigate losses;
9. Develop a culture of prevention of the risks in the city and to prepare the community to face earthquakes;
10. Start concrete and measurable actions for the mitigation of the risk with the participation of the community and different sectors of the city through an "Action Plan"

5.2. GOALS OF THE PLAN FOR THE MANAGEMENT OF THE SEISMIC RISK

1. Forming a Unit for the Reduction of the Risk in the city at the Municipio of Guayaquil, in order to institutionalize a sustained process and for the execution of the "Action Plan";
2. Training of the basic organizations in charge of the protection of the citizens on the prevention and mitigation of risk due to earthquakes;
3. Forming and training specialized groups in rescue operations, fires with dangerous substances and in the management of seismic emergencies;
4. Planning of the hospital and health services during and after an earthquake;
5. Planning social attention to those affected during and after an earthquake (temporary shelters, building reconstruction, etc);
6. Planning of a rapid response and recovery of the vital services and life lines of the City;
7. Updating or preparation of emergency or contingency plans for the City, its institutions and vital services;
8. Rehabilitating, modernizing and better maintening of equipment and vital services systems;
9. Studying in detail the safety of essential structures and to design the necessary measures to mitigate damage: strengthening, change of use, construction of new facilities, etc.;
10. Evaluating the vulnerability and reduce the risk of the productive infrastructure of the City facing earthquakes;
11. Identifying of buildings and infrastructure in risk, and promote projects of urban renovation in the zones of risk where obsolete buildings are predominant;
12. Making the Municipio of Guayaquil to implement a "Construction Code for the Design of Seismic Resistant Structures" to regulate new buildings and the inspection of existing structures;
13. Strengthening the control and safety measures against fire in industrial installations, gas stations, energy power plants, etc, and in old buildings;
14. Incrementing the monitoring and study of the seismic and geologic hazard;
15. Updating the knowledge of professionals about the seismic risk and the techniques to mitigate the loss of lives and economic losses;
16. Motivating the Institutions to incorporate in the stages of planning and design of new infrastructure, measures for the prevention and mitigation of risk;
17. Educating the people in the prevention of risks with basic regulations of self protection during the earthquake and of survival after the event;
18. Training the communities on the identification of their risks and in the preparation of contingency plans on a community level;
19. Supporting the communities in the construction of minor civil works for the reduction of risks;
20. Promoting that the productive sectors participate actively in the identification of the risks, the preparation of contingency plans for their sector, and concrete actions to reduce the loss of lives and economic losses during earthquakes.

5.3. DESIGN OF THE PLAN FOR THE MANAGEMENT OF RISK

The Plan for the Management of the Seismic Risk of Guayaquil is a master document which contains a list of activities related with the three stages of a disaster: Preparation, Attention and Recovery [10] – [11].

The Plan clearly identifies the present situation of the progress done in the different activities, it identifies responsibilities and recommends actions in the future.

5.4. INTERVIEWS AND DISCUSSION GROUPS

In order to prepare the Plan for the Management of the Seismic Risk and the Action Plan, individual meetings were scheduled and the "Workshop of the Action Plan" took place during the months of January to July, 1999.

The individual meetings were carried out with each of the nearly 30 institutions that prepared specific projects which form a part of the set of actions of the "Action Plan".

The Municipio of Guayaquil summoned six focal meetings to which more than 60 people attended. These meetings took place in the Municipal Museum and they had the goal of explaining to the representatives of over 40 institutions the objectives, goals and strategies of the Action Plan, group work to build consensus about the items to be included in the Plan and the motivation for the strengthening of the process.

The main event for the preparation of the Plan for the Management of the Seismic Risk and Action Plan was the workshop that took place on July 1 and 2, 1999. In this workshop the criteria and actions to be included in the plans were finally defined.

5.5. PREPARATION OF THE PLAN FOR THE MANAGEMENT OF RISK

Table 12 presents the Plan for the Management of Risk is presented. The ideal actions to be taken for the reduction of the risk are shown there, and the activities upon which work must be done in order to improve the preparation and recovery of the city facing seismic disasters are included.

The Plan has been prepared on the basis of a matrix given by GeoHazards International which has the associated activities to the three stages of disasters. Adding to this international experience is the knowledge the local experts have about the current situation of the Management of the Seismic Risk in Guayaquil, and the revisions and recommendations of the participants of the workshop on the Action Plan.

Table 12. Plan for the Management of the Seismic Risk of Guayaquil

Preparation stage facing disasters:

NECESSARY ACTIVITIES	RESPONSIBLE (S) ORGANIZATION (S)	CURRENT SITUATION OF ACTIVITIES	ACTIONS FOR THE FUTURE
Planning of the management of seismic risk of Guayaquil.	Civil Defense	There is no Plan for the management of the seismic risk of the City	Planning the management of risk through the Municipality of Guayaquil with the support of Armed Forces, Universities and specialized institutes.
Planning the response activities facing the emergency: search and rescue, fire fighting, safety, communications, etc.	Basic Organizations: Civil Defense Red Cross Armed Forces Police Fire Department Traffic Police	There is no contingency plan to face earthquakes in the city. The Civil Defense has general directives and the Red Cross has basic plan.	Promote a complete inter institutional plan. Strengthen the planning within the basic organization.
Planning the activities of social attention in shelters for water and food distribution, etc.	INNFA, Ministry of Social Welfare, Civil Defense, Armed Forces, Ministry of Education and Culture.	There is no plan. There is an experience of the management of shelters during El Niño 1997 – 1998, that may be useful	Integrate the institutions. Establish plans with the institutions for the management of shelters.
Planning for recovery after an earthquake, reconstruction of infrastructure, etc.	There is no specific organization in charge of the theme.	There is no planning for the recovery of the City	Involve the private sector. Initiate the municipal and governmental planning on these matters. Create a special fund.
Recommendations of policy related to the management of disasters.	Civil Defense	There is no improvement on this theme.	Professionalism of the Civil Defense in the Administration of risks. Ask for information and for national and International counseling.
Establishing and equipping an emergency operation Center in a seismic resistant building.	Civil Defense	The headquarters of the Civil Defense is located on a building without seismic resistant design.	Build an Operation Center on the most strategic place with the participation of many institutions.
Training of personnel for the emergency response.	Civil Defense Red Cross Armed Force Fire Department	There are basic programs for training facing earthquakes.	Strengthen the training of basic organizations and the population through the different neighborhood committees.

Training of builders, engineers, architects, planners and other professionals.	Not defined	Some isolated efforts by Universities and Professional Organizations.	Commitment the Construction Chamber to create mandatory programs in universities
Storage of supplies for emergencies, such as tents, canned food, etc.	Civil Defense	The Civil Defense has a storage room with some supplies to attend emergencies at his headquarters in the south of the city.	Store supplies at Military Bases. Make inventory controls. Build special storage rooms.
Investigation and monitoring of the seismic activity.	None	Universities and Polytechnic Schools make contributions to the theme.	Make a specialized International Center with foreign counseling.
Increment awareness among authorities about the seismic risk.	None	None	Publish simple documents. Communicate this issue to proper authorities.
Issuing of seismic codes of construction.	INEN is in charge of the national regulations and in 1977 issued the current Ecuadorian Code of Construction (CEC)	INEN has done nothing to reform the present CEC since 1977. An initiative of some universities with the support of FUNDACYT is taken place since 1998 to reform the Code.	Support and Control by the Municipality of Guayaquil. Coordinate with Construction Chamber. Involve universities, professional organizations. Make Ministry of Social Welfare responsible for non compliance.
Construction of new life lines with seismic resistant design.	None	None	Make public service organizations responsible. More control by Municipality of Guayaquil and Ministry of Public Works.
Control the construction of new public buildings with seismic resistant design.	Municipality of Guayaquil	None	Special Law for builders. More controls by Municipality of Guayaquil. Support from the Engineering and Architecture Professional Organizations.
Control the construction of new private buildings with seismic resistant design.	Municipality of Guayaquil	None	Strengthen regulation for builders. More control by Municipality of Guayaquil
Evaluation of the vulnerability of existing buildings and strengthening of the most vulnerable ones.	None	There is a study done by Universidad Catolica with the sponsorship of FUNDACYT for affordable housing	Analyze and apply Study from Universidad Católica with support of Municipality of Guayaquil, professional organizations and private sector.

Evaluation of the vulnerability of existing school buildings and strengthening of the most vulnerable ones.	None	There is a proposal made by Universidad Catolica for OAS in 1993.	Review proposal from Universidad Católica, make it better with support of MEC, professional organizations and other universities, seek financing .
Evaluation of the vulnerability of existing public buildings and strengthening of the most vulnerable ones.	None	There is a Study done by Universidad Catolica for DHA/UN from 1992 to 1994	Start from existing report and update it with support of proper organizations. Involve private sector.
Evaluation of the vulnerability of existing hospital buildings and strengthening of the most vulnerable ones.	None	There is a Study done by Universidad Catolica for PAHO/WHO and ECHO of the European Community in 1995	Start from existing report and update it with support of MSP. Involve Junta de Beneficencia and other health sectors.
Evaluation of the vulnerability of existing life lines and strengthening of the most vulnerable ones.	None	There are no previous experience on the evaluation of life lines.	Ask for national and international advise and train public service organizations.

Disaster attention stage:

NECESSARY ACTIVITIES	RESPONSIBLE (S) ORGANIZATION (S)	CURRENT SITUATION OF ACTIVITIES	ACTIONS FOR THE FUTURE
Leadership of search and rescue activities.	Civil Defense Red Cross	Generally the Armed Forces participate in this type of activities.	Give to the involved institutions better equipment with the International help. Include firemen is this task.
Extinguishing of fires generated by earthquakes	Fire Department	Firemen lack of specialized training.	Promote training with the International support.
Provision of emergency medical treatment.	Public Hospitals	Hospitals do not have plans to respond to a seismic emergency and their capacity is very limited.	Make special laws to oblige Health Centers to have emergency plans. Control and support from MSP.

Investigation and solution of dangerous materials spills such as oils, toxic waste, etc.	None	INEN has a committee to regulate the use of dangerous materials and institutions like Port Authority keep an inventory of dangerous substances and make controls at the Port	Make INEN to conduct a research with support of ESPOL, MICIP and Municipality of Guayaquil, as well as Ministry of Environment. Use a data base created by Port Authority.
Coordination of emergency response efforts of all the involved institutions.	Civil Defense	Institutions generally demand a more effective coordination.	Professionalism of the Civil Defense in the management of emergencies. Organize training courses with the participation of all basic organizations.
Coordination and management of foreign help.	Civil Defense	There is no planning on this issue. The PAHO promotes the use of SUMA, and the Red Cross deals with the help during emergencies.	Unite efforts and make one institution responsible for the total control with the support of the Armed Forces to avoid corruption.
Establishing of emergency shelters for families without homes.	None	During the last El Niño, INNFA was in charge of this activity, with the support of other institutions.	The Ministry of Social Welfare must make a plan with INNFA, Municipality of Guayaquil and other institutions of social assistance.
Gathering and distribution of help supplies (food, water, medicines, etc.).	Civil Defense	There are no plans on this issue.	Civil Defense must elaborate a plan with the support of Fire Department, Church, Boy Scouts, etc.
Execution of emergency repair to life lines (water, telephone, power, roads, etc.).	Public Service Organizations	There are no plans on this issue.	Make a special committee formed by public service organizations, under the direction of Municipality of Guayaquil. Implement a plan for rapid maintenance.
Cleaning debris that make emergency response actions difficult.	None	There are no plans on this issue.	The Direction of Public Work from Municipality of Guayaquil must have a plan with the support of Corp of Engineers and private sector.

Informing the people about what to do and where to go; E.g. location of emergency shelters and help supplies distribution Centers..	None	There are no plans on this issue.	The Civil Defense, Municipality of Guayaquil, INNFA, etc., must identify special places. The Direction of Press of Municipality of Guayaquil must elaborate a communication plan and form an information Center.
Identification of people dead and informing relatives.	None	There are no plans on this issue.	Make plans with the Civil Registrar, Forensic Medicine and Police.
Identification and restriction of dangerous areas.	None	There are no plans on this issue.	Make plans for training Police personnel and basic organizations.
Gathering and organizing information about the quantity and location of damage.	None	There are no plans on this issue.	Organize neighborhood brigades. Plan who will be in charge and ask universities to get involved.

Recovery from disasters stage:

NECESSARY ACTIVITIES	RESPONSIBLE (S) ORGANIZATION (S)	CURRENT SITUATION OF ACTIVITIES	ACTIONS FOR THE FUTURE
Gathering and organizing detailed information about damage and cost of repairing.	None	There are no plans on this issue.	Organize neighborhood brigades. Planning who will be in charge. Make universities get involved.
Decision about which structures are safe to be occupied again, which need repairing and which need to be demolished.	None	There are no plans on this issue.	Create a special unit with universities, the support of professional organizations (Engineers and Architects) and the Direction of Appraisal and Registrar of Municipality of Guayaquil.
Adequacy of places for temporary shelter construction or construction of houses for the affected people during the recovery process.	None	There are no plans on this issue.	Form an inter institutional committee, with Municipality of Guayaquil, MIDUVI and private sector for planning the adequacy of appropriate places.

Cleaning and disposal of debris.	None	There are no plans on this issue.	Coordination of Municipality of Guayaquil and Ministry of Public Works
Measures of urban planning such as widening of streets, change of routes, family relocation, etc.	None	The Municipality of Guayaquil has a Plan for urban renewal of areas socially very depressed in the Central Zone.	Create a unit at Municipality of Guayaquil within Office of Urban Planning for this kind of work. Support of the Ministry of Public Works.
Reconstruction and repairing of damage houses.	None	There are no plans on this issue.	Promote self procurement with financial support.
Reconstruction and repairing of damaged life lines such as water, power, telephone and roads.	Ministry of Public Health (in the case of public hospitals)	There are no plans on this issue.	Each organization of public service must make its own plan.
Reconstruction and repairing of damaged hospital buildings.	Ministry of Public Health (in the case of public hospitals)	There are no plans on this issue.	Reinforce hospitals at risk to protect them for damage during earthquakes.
Reconstruction and repairing of damaged schools.	MEC (in the case of public schools)	There are no plans on this issue.	Reinforce schools at risk to protect them for damage during earthquakes.
Reconstruction and repairing of monuments or damaged cultural buildings or churches.	None	There are no plans on this issue.	The National Institute of Historic Patrimony must have a plan.
Reconstruction and repairing of houses.	MIDUVI	MIDUVI, municipal governments, NGO's and Armed Forces have taken charge of the reconstruction of affected houses in the past earthquakes in Ecuador.	Strengthen planning
Obtaining and distributing financial aid to the affected citizens for the recovery of production.	None	None	Look for support from the private national and International sector

5.6. WORKSHOP ON THE ACTION PLAN TO REDUCE THE SEISMIC RISK OF GUAYAQUIL

The workshop on the Action Plan of RADIUS Project to reduce the seismic risk of Guayaquil took place on July 1 and 2, 1999, with the participation of 112 persons from more than 50 institutions.

The participants were summoned to:

a) Analyze projects prepared by institutions of the city. Eight representatives presented project profiles which were prepared in the preliminary version of the plan for discussion in this workshop.

b) Decide about other initiatives that must be incorporated, assign priorities and define an strategy for the implementation of the Plan.

c) Decide what must be done after RADIUS.

Figure 28. Some of the participants of the Workshop on the Action Plan for reducing the seismic risk of Guayaquil working in groups.

For the execution of the Workshop Tasks and following the eight categories of the Preliminary Action Plan, the following work groups were formed:

Group 1. Strengthening of physical safety and planning of hospital response

Formed by the Civil Defense, Provincial Direction of Health, Traffic Police of Guayas, ESPOL, Hospitals Abel Gilbert, Lorenzo Ponce, Luis Vernaza, Francisco De Icaza Bustamante and Teodoro Maldonado Carbo; Municipio de Guayaquil, Pan American Health Organization and Under Secretary of Health.

Group 2. Improvement of safety of installations, identification of equipment, infrastructure and materials at risk of public service organizations and industry.

Formed by Port Authority, Fire Department, ECAPAG, IESS, Municipio de Guayaquil, Electro - Guayas, II Air Zone and Pacifictel

Group 3. Improvement of safety of infrastructure in urban zones of high risk.

Formed by the Civil Defense, CARE, EMELEC, FISE, MIDUVI, Municipio and Universidad Católica.

Group 4. Intervention of buildings at risk and design of strengthening.

Formed by the Chamber of Insurance Companies of Ecuador, FISE, INOCAR, INNFA, Research Institute of Natural Sciences Faculty of University of Guayaquil, MIDUVI, Municipio de Guayaquil, Under Secretary of Education, Universidad Católica and "Hogar de Cristo Housing Project"

Group 5. Planning of a rapid response and recovery.

Formed by the II Military Zone, Chamber of Insurance Companies of Ecuador, Civil Defense, EMELEC, INNFA, INOCAR, Junta de Beneficencia de Guayaquil, Municipio de Guayaquil, Under Chamber of Insurance Companies of Ecuador Secretary of Public Works, United Nations, Universidad Católica, GeoHazards International.

Group 6. Specialized training in rescue tasks and training of basic organizations.

Formed by Simon Bolivar Airport, Civil Aviation, Association of Boy Scouts of Ecuador, Infantry Brigade No. 5 Guayas, Red Cross, Fire Department, Civil Defense, Provincial Direction of Education, Municipio de Guayaquil, Nacional Police and SECAP.

Group 7. Preparation of the people to face earthquakes and mitigation of the risk in organized communities.

Formed by Concejo Cantonal de Guayaquil, Red Cross, Diario El Universo, Municipio de Guayaquil, Radio El Telégrafo

Group 8: Strengthening of regulations and technical knowledge.

Formed by Chamber of Insurance Companies of Ecuador, Professional Organizations from Guayas (Engineers and Architects), Ecuadorian Committee of Geologic Sciences, ESPOL, INOCAR, Universidad Católica, Universidad de Guayaquil.

The main suggestions of the participants to the workshop concerning the objectives, current structure, and other initiative that should be incorporated to the Action Plan were:

a) Organize the communities, prepare them and educate them in the prevention and mitigation of risks, with the participation of all organizations: Municipality, Armed Forces, etc.;
b) Ask for technical support and advise from developed countries like Japan;
c) Make the National Government support all projects from the Action Plan, because, according to the Constitution, the State must protect all citizens;

d) Inspect the stadiums and coliseums of some schools, specially those that gather hundred of students;
e) Make The Municipality of Guayaquil responsible for the new buildings to be seismic resistant designed. This regulation must be included in the municipal ordinances;
f) Include in the Programs of Study of elementary schools subjects such as the preparation of population to face earthquakes and the mitigation of the seismic risk;
g) Divulge knowledge about earthquakes through the media and what it is expected from the community;
h) Reduce the eight categories of projects considered to appropriately six for a better coordination of the projects;
i) Include the process of recovery in the Plan, including the psychological rehabilitation after the disaster;
j) Improve the Civil Defense coordination system which must function according to its present legal structure, without being dedicated only to the operative part but also to planning;
k) Promote plans for prevention and contingency plans at the public and private institutions. The hospitals must especially be prepared for any kind of disaster.

About the strategies to implement the Action Plan and what must follow after RADIUS, the main opinions were:

a) Create a permanent Inter Institutional Committee for the control of the execution of the Plan;
b) Corruption must be prevented, including all institutions involved in the process, gaining credibility with a realistic plan, everybody should know the plan, and political interests should not be allowed to spoil it;
c) Keep the motivation among the institutions and the community, working closely with the media, incorporating the plan within the Municipality, organizing seminars for leaders of the community, organizing periodic meetings for opinion interchange, etc.;
d) Manage to obtain social recognition and economic support establishing commitmentss to obtain support for the plan by government and municipal authorities, informing potential international donors through a web site on the Internet and exposing clearly costs and benefits of the plan, searching for financial sources such as a tax to the insurance of buildings against fires, a tax on the electricity bill, etc.;
e) Support the individual initiatives and make a commitment with the universities to support the execution of the plan, coordinate with the Ministry of Education to make students aware of the plan, exchange experiences with other countries, promote the execution of projects similar to RADIUS in other cities of Ecuador, evaluate the progress of the plan every six months, etc.

The participants to the workshop were asked the specific question about which Institution should coordinate the execution of the Action Plan of RADIUS Project; five of the eight work groups said that the Municipality of Guayaquil should be the chosen institution; one work group said that the Civil Defense should be strengthenes and given such role; another group said the Armed Forces; and one group did not make a specific answer.

5.7. THE ACTION PLAN

The Action Plan has projects or specific actions that the institutions of the city have committed to execute in order to reduce the seismic risk. Following the recommendations of the Workshop, the projects have been grouped within six categories assigning their corresponding priorities. The Plan is shown in table 13.

Table 13. Action Plan to reduce the Seismic Risk of Guayaquil

Category 1: Strengthening of the physical safety and planning the response of hospitals

Projects or actions	Responsible Institution	Beneficiaries	Priority
1. Updating of the emergency plan of Hospital General Vernaza and coordination with other health institutions	Junta de Beneficencia	The hospital + community	High
2. Signaling evacuation routes and identification of vulnerable equipment and installations at Hospital Luis Vernaza.	Junta de Beneficencia	Users and employees	High
3. Design and construction of evacuation staircase for Pensionado Sotomayor at Hospital Luis Vernaza	Junta de Beneficencia	Users and employees	Low
4. Evaluation of non structural elements, life lines at the hospitals of Guayaquil	Under Secretary of Health	All community	High
5. Repair and maintenance of life lines at Hospital Regional IESS, Dr. Teodoro Maldonado Carbo.	IESS	Inhabitants of the South	Low

Category 2: Improvement of safety and identification of equipment, infrastructure and risky materials on life lines and industrial installations.

Projects or actions	Responsible Institution	Beneficiaries	Priority
6. Strengthening of maintenance of the production infrastructure and winning of water of Potable Water Plant La Toma	Ecapag	All community	High
7. Reduction of the seismic risk at the installations of the Sea Port of Guayaquil	Port Authority	Users and operators	Done
8. Evaluation of the seismic risk of the transmission and distribution system of energy power of Guayaquil	EMELEC	All City	High
9. Evaluation of the potential losses at the thermoelectric plants of El Salitral, Trinitaria and Pascuales	Electro - Guayas	All Province	High
10. Inventory of infrastructure and hazardous materials in industries and power installations in the City	Fire Department	All City	High

11. Evaluation of alternate routes for emergencies situations	Min. OO.PP, Municipality of Guayaquil	All City	High
12. Evaluation of seismic risk on the telephone system	Pacifictel	All community	High
13. Evaluation of seismic risk to port installations	FF.AA.	The Country	High
14. Substitution of priority networks and evaluation of distribution networks of potable water	Ecapag	60.000 inhabitants	Low

Category 3: Improvement of infrastructure in urban zones with risk, identification of buildings at risk and design of retrofitting.

Projects or actions	Responsible Institution	Beneficiaries	Priority
15. Provision of basic services for shelters	FISE	All community	High
16. Identification of buildings at risk in the housing projects built by JNV-BEV	MIDUVI	100.000 inhabitants	High
17. Identification of vulnerable buildings of INNFA: day care centers, building headquarters, etc.	INNFA	60.000 inhabitants	High
18. Identification of buildings at risk and design of retrofitting	Municipality of Guayaquil and owners	All community	High
19. Issuing a construction code for the city	Municipality of Guayaquil	All community	High

Category 4: Planning of a rapid response and recovery of the City from an earthquake.

Projects or actions	Responsible Institution	Beneficiaries	Priority
20. Evaluation of functioning of shelters during El Niño 1997 – 1998.	INNFA	All community	High
21. Analysis of damage/losses of goods/property during past earthquakes and preparation of a data base of insured and not insured buildings	Chamber of Insurance Companies	All community	High
22. Gathering/supplement of information for risk maps and seismic vulnerability maps; inventory of buildings and infrastructure of the City and making an administrative program of risks and protection by means of insurance policy.	Chamber of Insurance Companies	All community	High

23. Informing the benefits of insurance, education of the use of it and claim of insured goods.	Insurance Chamber	All community	High
24. Analysis of cover of insurance policies against fires, sponsored by the Ministry of Social Welfare	Chamber of Insurance Co.	All community	High
25. Making of a plan for the removal of debris for the City of Guayaquil	Municipality of Guayaquil	All community	High
26. Forming of a Technical/Administrative Unit for the appraisal of claiming the insured goods	Chamber of Insurance Co.	All community	High
27. Planning of the air support during an emergency	Armed Forces	All community	High
28. Planning of the role of institutions in the control and order of traffic at areas of greatest seismic impact	Traffic Police	All community	High

Category 5: Training to the basic organizations of the Civil Defense and the community to face earthquakes

Projects or actions	Responsible Institution	Beneficiaries	Priority
29. Specialized training in rescue operations in dangerous situations to basic organizations (fire, toxic substances, etc.)	Port Authority	Basic organizations	High
30. Education of the Traffic Police of Guayas	Traffic Police	Traffic Police	Low
31. Training of Neighborhood Brigades	National Police	All Community	High
32.Training to workers on seismic prevention through educational programs	SECAP	Workers	High
33. Training to the different sectors of the community in the prevention and mitigation of risk.	Civil Defense	All community	High
34. Training of the volunteers from the Boy Scouts to face a seismic emergency	Boy Scouts	All community	High
35. Plan of industrial self protection and of the communities supported by INNFA to face earthquakes	INNFA	60.000 persons	High
36. Training for disaster prevention by means of the development of risk maps, auto protection and contingency plans at the community level	Red Cross	Communities on marginal zones	High
37. Preparation of the community at all levels through the media and the Civic Municipal Committees	Municipality of Guayaquil	All community	High

Category 6: Strengthening of the seismic regulation and the technical knowledge

Projects or actions	Responsible Institution	Beneficiaries	Priority
38. Knowledge Update Courses about Seismic Resistant Design and Construction Techniques	Professional Org. (Eng.)	Civil Engineers	High
39. A Guide for the mitigation of the seismic risk in the urban marginal wood houses	Universidad Católica	Poor Communities	High
40. Courses about Architectural Design for the reducing of seismic risk	Professional Org. (Arch)	Architects	High
41. Municipal Ordinance for the control of seismic resistant building construction	Municipality of Guayaquil	All City	High
42. Seismic and Tectonic Monitoring	Universities	All community	High
43. Courses about seismic tectonic knowledge	ESPOL	All community	High

6.1. PUBLIC RELATIONS ACTIVITIES

The work done and the obtained results have had an ample coverage by the communication media, locally and internationally. Close to 100 press releases about the Project and the Workshops have been published on the newspapers (67), broadcast on radio (17) and shown on television (15), from February 1998 to August 1999.

The results of the RADIUS Project have been adequately presented to the public with this type of press coverage, and a big step forward has been given towards the construction of a community culture of prevention and mitigation of risks.

Examples of two press news, a complete page is shown on figures 29 and 30.

Proyecto Radius revela deficiencias en construcciones

Guayaquil: Ciudad vulnerable

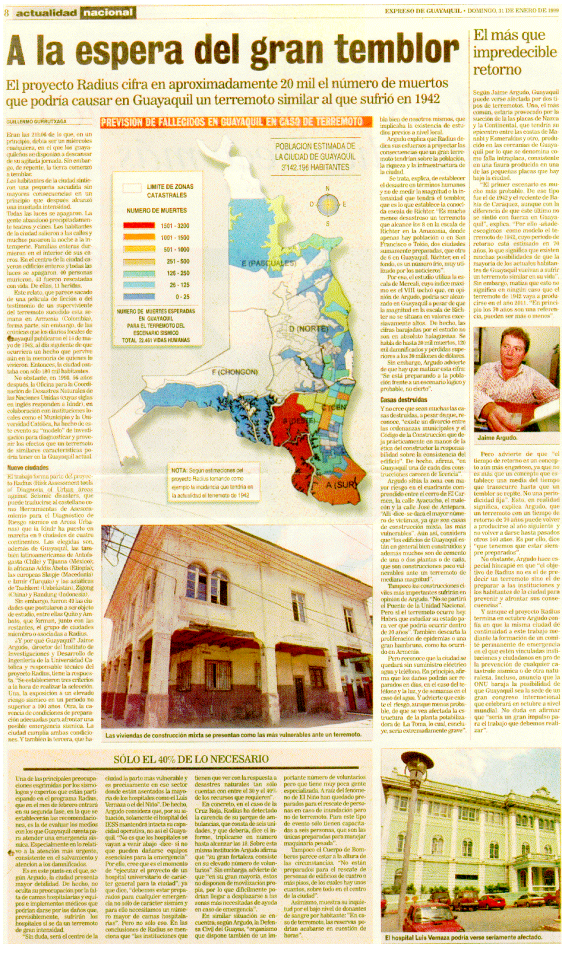
Edificios de servicio público

Líneas vitales

Infraestructura vial

Casas de salud

Figure 29: El Universo Newspaper, January 24, 1999



actualidad nacional

A la espera del gran temblor

El proyecto Radius cifra en aproximadamente 20 mil el número de muertos que podría causar en Guayaquil un terremoto similar al que sufrió en 1942

El más que impredecible retorno

Casas destruidas

SÓLO EL 40% DE LO NECESARIO

Figure 30: Expreso Newspaper, January 31, 1999

6.2. NATIONAL AND INTERNATIONAL TRAINING SEMINARIES

During the execution of the Project, the following persons received training:

a) Mr. Walter Mera, (Universidad Católica de Santiago de Guayaquil), participated in the 12th International Seminar on Seismology and Earthquake Engineering at Tsukuba Japan, from May 11 to June 19, 1998, with the sponsorship of JICA and organized by IISEE - BRI from the Ministry of Construction of Japan;

b) Mr. Nastenka Calle (Municipio de Guayaquil) participated in the Course for Municipal Functionaries, from 22 to 30 June, 1998 at Tokyo and Fukui, Japan, sponsored and organized by the University of the United Nations, the UN Center for Regional Development and the Secretary of the IDNDR;

c) Arq. Jessica Vinces (Municipio de Guayaquil) and Mr. Julio Peña (Universidad Católica de Santiago de Guayaquil) participated in the Course for the operation of the MGE Geographic Information System from 6 to 17 July, 1998, at the Geographic Pan American Study and Research Center (CEPEIGE) in Quito.

6.3. DISSEMINATION OF THE INFORMATION AND EDUCATION

Some complementary activities to those originally planned have taken place for a better dissemination of the results of the Project. The following is a list of these activities:

a) Presentation of a Conference on the Seismic Scenario and technical support to INNFA functionaries for the design of three project profiles for the Action Plan. This was accomplished in a one day Workshop that took place on May 1999 with the presence of near 40 functionaries of INNFA;

b) Preparation of a 9 page Report about the seismic vulnerability of the installations of potable water and sewage system of Guayaquil for ECAPAG, the organization that provides this service;

c) Preparation of a 2 page Report about the seismic vulnerability of the Chamber of Commerce building of Guayaquil;

d) Many work sessions with the main functionaries of relevant institutions of the City took place, with the purpose of presenting RADIUS, the most important sessions were celebrated with the functionaries of the professional organizations of civil engineers and architects. From those sessions important commitments were established for the organization of future events that will contribute to the promotion of the results of the Project and to give training to professionals on the field of "Construction and Design of Seismic Resistant Structures".

CHAPTER 7: CONCLUSIONS

7.1. EVALUATION OF THE PROJECT AND FULFILLMENT OF THE OBJECTIVES

The evaluation of RADIUS Project is very positive and extremely satisfactory. The proposed objectives have been widely fulfilled, with the following goals accomplished:

e) Evaluation of the risk of Guayaquil facing three sources that could generate earthquakes of great hazard, and developing a hypothetical scenario of damages due to an earthquake of Intensity VIII, as shown in Chapter 4;

f) Preparation of a plan for the Management of the Seismic Risk and an Action Plan based on the results of the evaluation of the seismic risk. This Plans is explained in Chapter 5, notice that the majority of the 43 projects are backed up by solid institutional commitments and formulated detailing the methodology, time table of activities and necessary resources for its execution;

g) Increasing awareness about the seismic risk to the public and authorities. This is explained in Chapter 6, by using an ample media coverage it has been possible to make the people conscious about the risk and to motivate local authorities to initiate immediate actions to reduce the risk;

h) Initiation of an institutionalization process to support the efforts for the mitigation and reduction of the seismic risk. The Municipio of Guayaquil has decided to create a "Unit for the Reduction of Risks" in order to give sustainability to institutionalize the risk management in the city.

7.2. INITIATIVES TO BE CARRIED OUT IN THE FUTURE

The results of the project motivated the majority of the institutions of the city to nominate the Municipio of Guayaquil as the most suitable institution to take the leadership for the execution of the Action Plan of the RADIUS Project.

Besides taking the decision of creating the "Unit for the Reduction of Risks", the Municipio of Guayaquil has started the negotiations to give Universidad Catolica de Santiago de Guayaquil the contract to prepare a "Seismic Resistant Design and Construction Code for Guayaquil". This project is one of the three specific actions that the Municipio of Guayaquil made the commitment to execute as part of the Action Plan.

REFERENCES

1. ARGUDO J., et al. “Leyes de Atenuación del movimiento del terreno bajo solicitaciones sísmicas”. Proyecto de Investigación CONUEP - Universidad Católica de Santiago de Guayaquil. Documento inédito. Guayaquil, 1999.
2. ARGUDO J., et al. “Vulnerabilidad Sísmica de Viviendas de Interés Social en Guayaquil”. Proyecto Fundacyt-Bid-Universidad Católica de Santiago de Guayaquil. Documento inédito. Guayaquil, 1997.
3. ARGUDO J. – YELA R. “Memorias del proyecto vulnerabilidad estructural de hospitales de Guayaquil”. OPS/OMS , ECHO, IIFIUC - Universidad Católica. 1995.
4. ARGUDO J., YELA R. “Microzonificación Sísmica de Guayaquil”. Memorias de las VIII Jornadas Nacionales de Ingeniería Estructural. Universidad Central del Ecuador, Facultad de Ingeniería, Ciencias Físicas y Matemática. Quito, 1994.
5. ATC, APPLIED TECHNOLOGY COUNCIL, 1985. Earthquake Damage Evaluation Data for California, Report ATC-13, Redwood City, California, USA.
6. CERESIS. Catálogo Sísmico del Ecuador. Proyecto SISRA.
7. CODIGEM. Mapa Geológico del Ecuador a escala 1:100.000 del Ministerio de Energía y Minas y la Cooperación Británica, 1973.
8. ECAPAG. Evaluación de los sistemas existentes. Programa de concesión de los servicios de Agua Potable y Alcantarillado de Guayaquil. Consultora Banque Paribas. 1997.
9. FUENTES A. Entrevistas a 20 instituciones operadoras de servicios e instalaciones vitales de la ciudad de Guayaquil. 1998 - 1999. Anexo A1 del proyecto RADIUS.
10. GEOHAZARDS INTERNATIONAL, 1994, The Quito, Ecuador, Risk Management Project, An Overview, Published by GeoHazards International, San Francisco, USA.
11. GEOHAZARDS INTERNATIONAL, NSET – Nepal, 1999, The Kathmandu Valley´s Earthquake Risk Management Action Plan, Published by the National Society for Earthquake Technology–Nepal, Kathmandu, Nepal.
12. MARIN L., “ Zonificación Geotécnica de áreas con riesgos por lluvias intensas de laderas de Guayaquil”. Sociedad Ecuatoriana de Mecánica de Suelos y Rocas, 1997.
13. MERA W. “Vulnerabilidad Sísmica de Guayaquil”. Artículo para el Boletín No 5 de la Coordinación de Investigación de la Universidad Católica de Santiago de Guayaquil. Guayaquil, 1991. Pags. 12-34.
14. RIPALDA O. “Evaluación de los daños producidos por el fenómeno de El Niño 1982 –1983”. Revista de Investigación No. 10. Universidad Católica de Guayaquil, 1998.
15. RUFILLI A. “Lecciones de Estructuras”. Capítulo II: Los Terremotos de Guayaquil. Universidad de Guayaquil, Departamento de Publicaciones. Guayaquil, 1949. Pags 265-290.
16. SAUTER, F. and SHAH, H., 1978, Studies on Earthquake Insurance, Proceedings of the Central American Conference on Earthquake Engineering, Vol. II, San Salvador, El Salvador.
17. UNIVERSIDAD DE GUAYAQUIL. Editorial Universitaria. Plano de Guayaquil después del incendio del 5 de Octubre de 1896 – Lámina 11-12. Julio de 1987.

18. VARNES D. J. " Landslide hazard zonation: a review of principles an practice" . International Association of Engineering Geology – Commission on Landslides and Other Mass Movements on Slopes. 1984.
19. VILLACRÉS A., ISHIDA H. "Análisis de Riesgo Sísmico para la costa noroeste del Ecuador usando datos de magnitud e intensidad". Memorias el I Congreso Internacional en Riesgo Sísmico CIRS-96. Universidad Católica de Santiago de Guayaquil – Universidad de Lecce (Italia). Guayaquil, 1996.

AUTHOR AND COLLABORATORS

THE AUTHOR

Mr. Jaime Argudo
Responsible Scientist of the Project
Research and Development Institute of the School of Engineering (IIFIUC)
Universidad Católica de Guayaquil - Apartado Postal 4671
E-mail: jargudo@ing-ucsg.edu.ec
jargudo@ucsg.edu.ec

THE COLLABORATORS

Mr. Walter Mera
Structural Vulnerability Analysis Specialist
E-mail: wmera@ucsg.edu.ec

Mr. Alex Villacrés
Seismic Risk Analysis Specialist
E-mail: alexv@ucsg.edu.ec

Mr. Julio Peña
Geographical Information Systems Specialist
E-mail: jpena@ucsg.edu.ec

Ms. María Elena Arellano
Journalist
E-mail: ame@ucsg.edu.ec

RADIUS team members
Research and Development Institute of the School of Engineering (IIFIUC)
Universidad Católica de Guayaquil – P.O. Box 4671

ANNEX 1 : STEERING COMMITTEE OF RADIUS PROJECT

NAME	RESPONSIBILITY	ADDRESS
Dr. Carlos Villacís	International Co-Director of RADIUS	GeoHazards International Stanford CA.
Mr. Guillermo Arguello	Local Co-Director of RADIUS, and Director of the Office of Urban Development Plan of the Municipality of Guayaquil (DPLAN-G)	Municipio of Guayaquil 10 de Agosto y Pichincha, 1er Piso
Dr. Rosalba Medina	Technical Advisor of Habitat-UN. For Project ECU-94-005: "Support to Municipio of Guayaquil".	"
Mr. Walter Mera	Dean of the School of Engineering of Universidad Católica de Santiago de Guayaquil and member of RADIUS Project	Facultad de Ingeniería - Universidad Católica de Guayaquil Ave. C. J. Arosemena Km. 1 ½
Ms. Gloria Gallardo	Director of Civic Promotion, Press and Publicity of Municipio of Guayaquil	Municipio of Guayaquil 10 de Agosto y Pichincha, 1er Piso"
Mr. Pedro Triviño	Director of Computer Systems Department of Municipio of Guayaquil	"
Mr. José Navarrete	Functionary of the Office of Urban Development Plan of the Municipality of Guayaquil (DPLAN-G) and member of RADIUS Project.	"
Ms. Mara Vieira	Functionary of the Office of Urban Development Plan of the Municipality of Guayaquil (DPLAN-G) and member of RADIUS Project.	"
Ms. Nastenka Calle	Functionary of the Office of Environment and member of RADIUS Project.	"
Ms. Jaime Argudo	Director of the Research and Development Institute of the School of Engineering (IIFIUC) and Scientific Responsible of RADIUS Project.	Facultad de Ingeniería - Universidad Católica de Guayaquil Ave. C. J. Arosemena Km. 1 ½

ANNEX 2: MEMBERS OF THE WORK GROUPS OF RADIUS PROJECT

WORK GROUP	MEMBERS	INSTITUTION
1. Administrative Activities of the Project	Mr. José Navarrete, Arq. Mara Vieira	DPLAN-G of Municipio
	Mr. Jaime Argudo	Universidad Católica
2. Preparation and data gathering	Ms. Mara Vieira, Ms. Jéssica Vinces	DPLAN-G of Municipio
	Mr. Gilberto Castro, Mr. John Galarza	Computer Systems Dept. of Municipio
	Mr. Angel Fuentes, Mr. Julio Peña	Universidad Católica
3. Research and development of Vulnerability Functions and identification of elements at risk.	Mr. Walter Mera, Mr. Jaime Argudo, Mr. Alex Villacrés	Universidad Católica
	Mr. Felipe Huerta	DPLAN-G of Municipio
4. Evaluation of Seismic Hazard, Selection of earthquake for the Seismic Scenario and Study of Collateral Risks.	Mr. Alex Villacrés, Mr. Jaime Argudo, Mr. Oswaldo Ripalda	Universidad Católica
5. Interviews with over 20 institutions and preparation of reports	Mr. Ángel Fuentes, Mr. Jaime Argudo	Universidad Católica
	Mr. José Navarrete, Mr. Felipe Huerta,	
	Mr. Juan Torres	DPLAN-G of Municipio
6. Diagnosis of damage and preparation of the Seismic Scenario for the adopted earthquake	Mr. Jaime Argudo, Mr. Alex Villacrés, Mr. Walter Mera, Ms. María Elena Arellano	Universidad Católica
7. Training	Ms. Nastenka Calle	Environmental Department of Municipio
	Ms. Jessica Vinces	DPLAN-G of Municipio
	Mr. Walter Mera, Mr. Julio Peña	Universidad Católica
8. Workshops of the Seismic Scenario and Action Plan	Mr. Jaime Argudo, Ms. María Elena Arellano, Mr. Augusto Alvarado	Universidad Católica
	Mr. José Navarrete	DPLAN-G Municipio
9. Preparation of the Plan for the Management of Risk and Action Plan.	Mr. Jaime Argudo	Universidad Católica
10. Diffusion of the Project on the media	Ms. Rocío Soria	Civil Promotion, Press, Publicity of Municipio
	Ms. María Elena Arellano	Universidad Católica
11. Preparation of reports and technical memoirs	Mr. Jaime Argudo, Mr. Walter Mera, Mr. Alex Villacrés, Mr. Julio Peña, Ms. María Elena Arellano.	Universidad Católica