# A VULNERABILITY STUDY OF THE HOSPITAL DR HORACIO E. ODUBER, ARUBA

## 1.- INTRODUCTION

Extensive areas in Latin America and the Caribbean are exposed to natural hazards of geologic and hydro-meteorological character such as: earthquakes, volcanoes, landslides, hurricanes, tsunamis and floods. From the particular point of view of the seismic hazard, it is believed that six out of every ten inhabitants, south of Rio Grande, excluding Brazil, live in areas likely to suffer potentially destructive earthquakes. Moreover around 50% the about 19.000 existing hospitals in the Latin America and the Caribbean are located in high rise zones. Only in the last fifteen years, more than 90 hospitals and 540 health centers collapsed or suffered heavy damage (OPS, 1997). Therefore, around 24.000 beds has been left out of service during that period. Such a thing is a consequence of the vulnerability of those structures to the seismic action. The losses for this reason overpasses three thousand million dollars (OPS, 1997)

Experience from past earthquakes demonstrates that prevention can substantially reduce damage in buildings, which has allowed this kind of institutions to cope with the external emergency service they provide, even during the immediate critical phase. To know what kind of preventive actions are needed, an evaluation of the seismic vulnerability is required.

## 2.- OBJECTIVES

The Pan American Organization of Health (POH) has requested us to make a study to evaluate in a qualitative way the functional and structural vulnerability of the Hospital Dr Horacio E. Oduber, located in the L.G. Smith Boulevard, Oranjestad, Aruba, to the eventual occurrence of earthquakes, hurricanes, tsunamis, floods and/or landslides.

## 3.- GENERAL APPROACH

The qualitative evaluation of vulnerability casts information on the kind of actions to be taken, that in a general way can be grouped as follows:

a.- Very low cost/benefit actions that allow a substantial reduction of functional vulnerability; for instance, to place a fixing device to secure the gas vessels as shown in Photo 1.

b.- Actions related to the eventual interventions of the bearing capacity of the structural system; whose decisions should be taken, normally, requiring further study.

The first group of actions are oriented to guarantee the operational capability of the building, in particular after the occurrence of a low to moderate intensity seism; its cost and planning can be incorporated to the preventive actions that are normally managed by the maintaining service.

The second group of actions is essentially limited by the availability of information: the lack of the structural project, what is frequent; the lack of geotechnical and natural hazard studies that represent a serious limitation to offer a reasonably and rigorous verdict about the structure safety, which is the required information to know the probability of failure. In the particular case of earthquakes, with the lack of part or all of the required data mentioned above, the evaluation on the safety fundamentally relies on more general criteria, among them we have:

(a) An eventual risk of unstability of the subsoil under expected seismic actions, in particular the conditional probability of failure due to liquefaction; if this probability exceeds values of the order of 10% to 20% of the design earthquake, the foundation system becomes of paramount importance.
(b) The average stress in the bearing structural elements under permanent loads; in other words, the relation between the total weight of the building and the area of the supporting elements.
(c) The behavior of the building structure in strong earthquakes observed in constructions with similar supporting systems, with comparable geometry and slenderness coefficient, and designed with the same criteria; for this reason it is important to know the date and the adopted hypothesis of the original project.

In order to undertake this study, an inspection visit was carried out during the lapse November 30th through December 2nd, 2000, with the purpose of making a general recognition of the buildings of the hospital complex. Likewise, information about the original structural project and geotechnical reports of the area of interest were requested, but they were not available. It must be pointed out that lack of adequate information will cast uncertainty in the forecast of structure behavior.

## 4.- EVALUATION OF THE NATURAL HAZARDS IN THE ISLAND

The Island of Aruba is located in the southern part of the Caribbean Sea, at 12.5°N and 70°W, to the northwest of Venezuela. The island is subjected to the action of different kinds of geologic and meteorological phenomena. In this study three hazards are fundamentally considered:

earthquakes, tsunamis and hurricanes. The uncertainties in the forecast of the frequency and intensity of these natural phenomena is a well known fact, that is why they are called natural hazards.

### 4.1.- Earthquakes

#### 4.1.1.- Active faults geologic outline

The Aruba Island is located in Caribbean Tectonic Plate which is located between the North America and South America plates ( Figure 1). The border between the Caribbean and the South America plates is evidenced by the right lateral fault systems of El Pilar-San Sebastian-Bocono, in Venezuela (Giraldo,1990); Aruba Island lies some 30 km north of the Paraguana Peninsula, in the Falcon State, Venezuela. It is considered a medium seismicity zone. Because of the lack of information on active faulting in the Aruba island, we use the neotectonic map of Venezuela (FUNVISIS, 1993) as a reference. In this map two parallel faults appear flanking the island on both sides, with an orientation northwest-southeast (Figure 2), which has been inferred by geophysical methods, but there is not information about their seismic potential. The nearest known active faults in the venezuelan territory are the following (see Figure 2):

(i) Pueblo Nuevo Fault, lying about 50 km from Aruba, has a seismic potential to generate an earthquake of magnitude 6.6 and a return period of some 2.300 years.

(ii) Cuiza Fault, some 120 km afar, has a capability to generate a seism of magnitude 6.7, with a return period of 1.500 years.

(iii) Eastern Oca Fault passes some 160 km south of the island and has a seismic potential to produce an earthquake of magnitude 7.5, with a return period of 390 years (Giraldo, 1993).

Briefly stated, from those faults located in the area of Venezuela, it is the Eastern Oca Fault the one that represents the highest seismic hazard for Aruba, due to its short return period and seismic potential.

#### 4.1.2.- Seismicity

Historically Aruba has been affected by very few earthquakes. These have caused some damage but were not of a destructive character. Figure 3 shows the seismic activity in the Caribbean area, around Aruba, for the 1910-1996 period, according to the seismicity map of Venezuela (FUNVISIS, 1997), and Figure 4 shows the seismic activity in the same area during the 1960-1996 period, for earthquakes above magnitude 3.5. In those figures we can see that around the Aruba island there are epicenters with magnitudes higher than 3.5, what indicating the existence of active seismic sources in the neighborhood of the island.

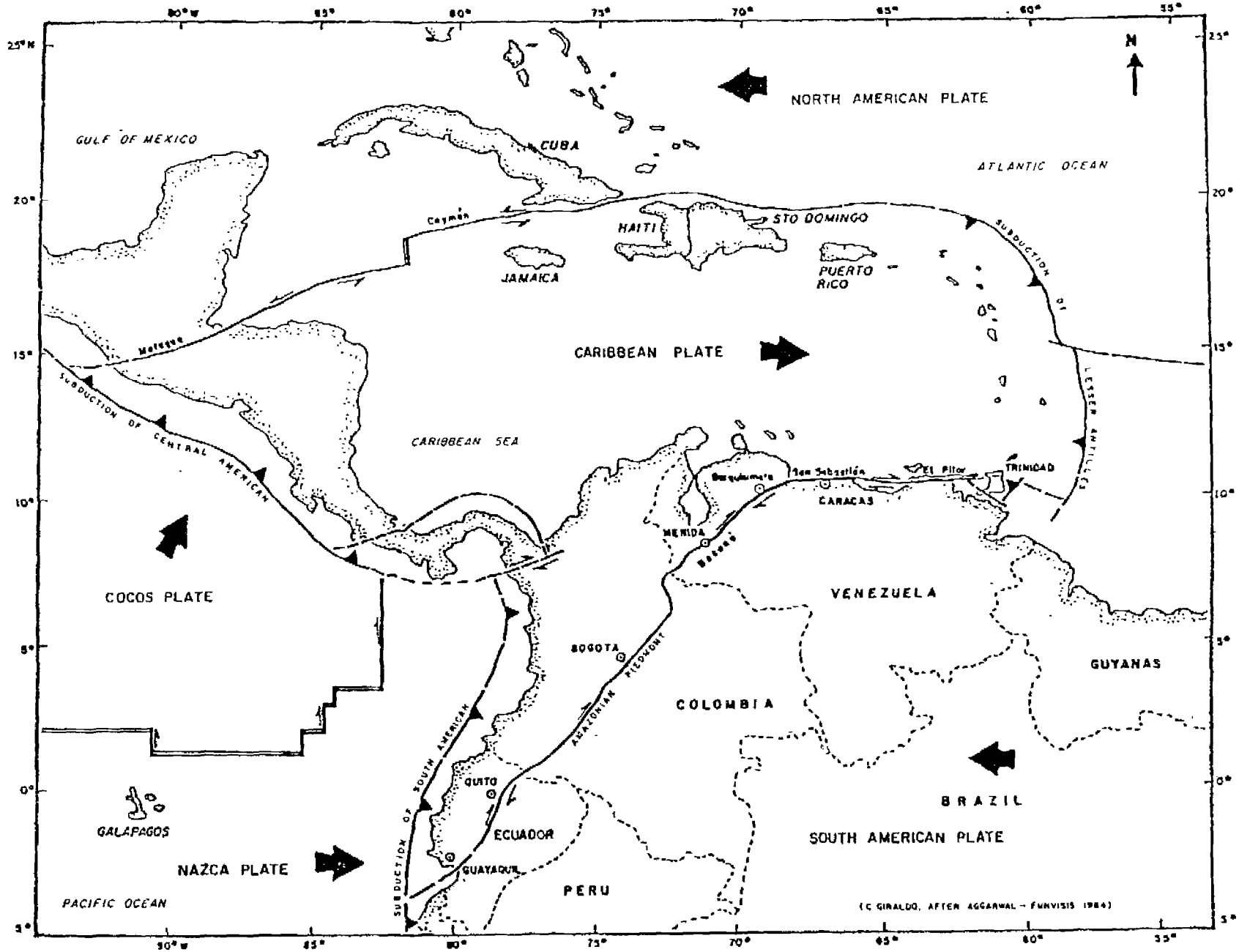



**FIGURE 1 Geodynamics Setting of the Caribbean Region (modified after Giraldo 90)**

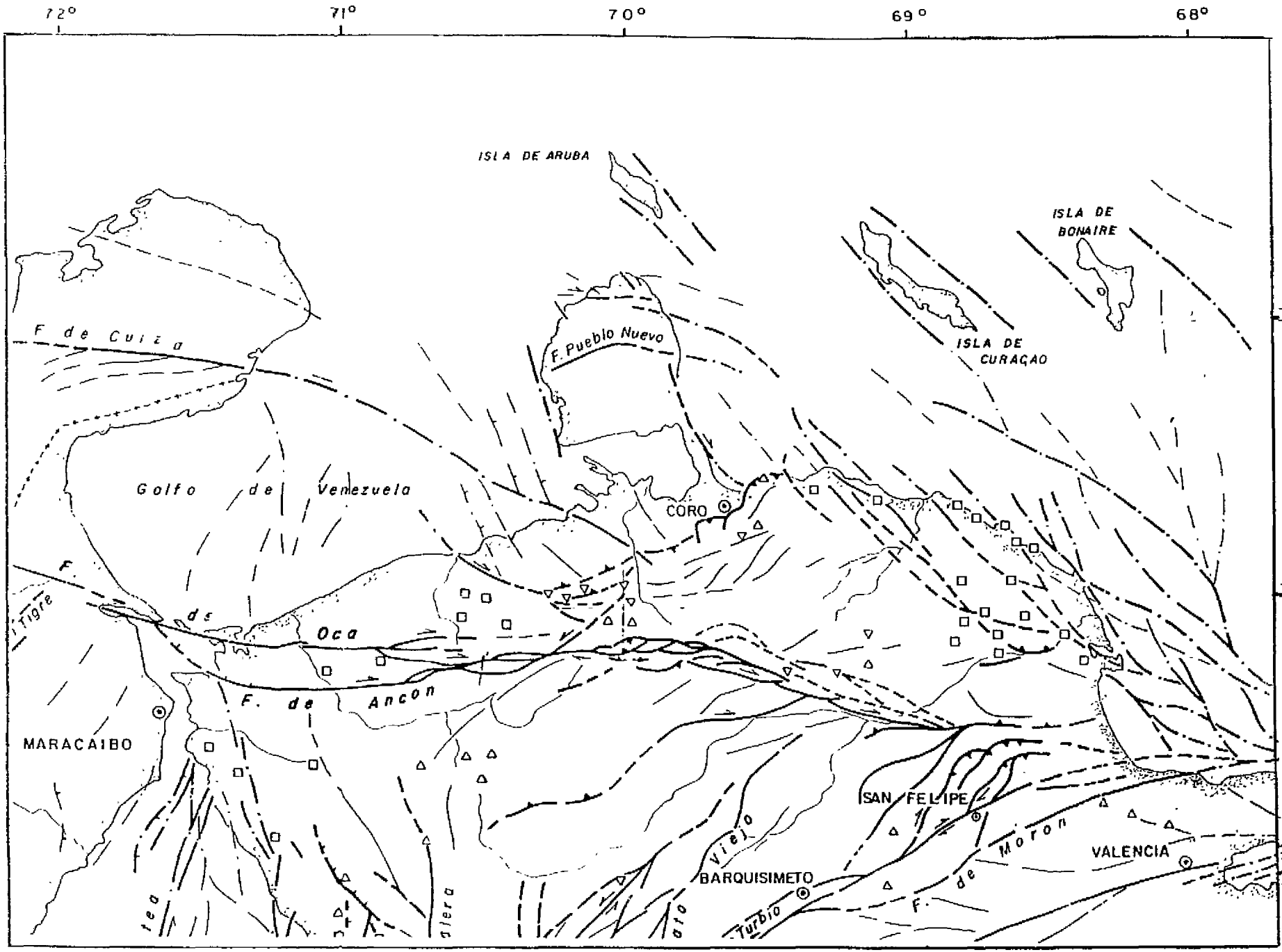



**FIGURE 2 Neotectonic Map of North-Western Venezuela**

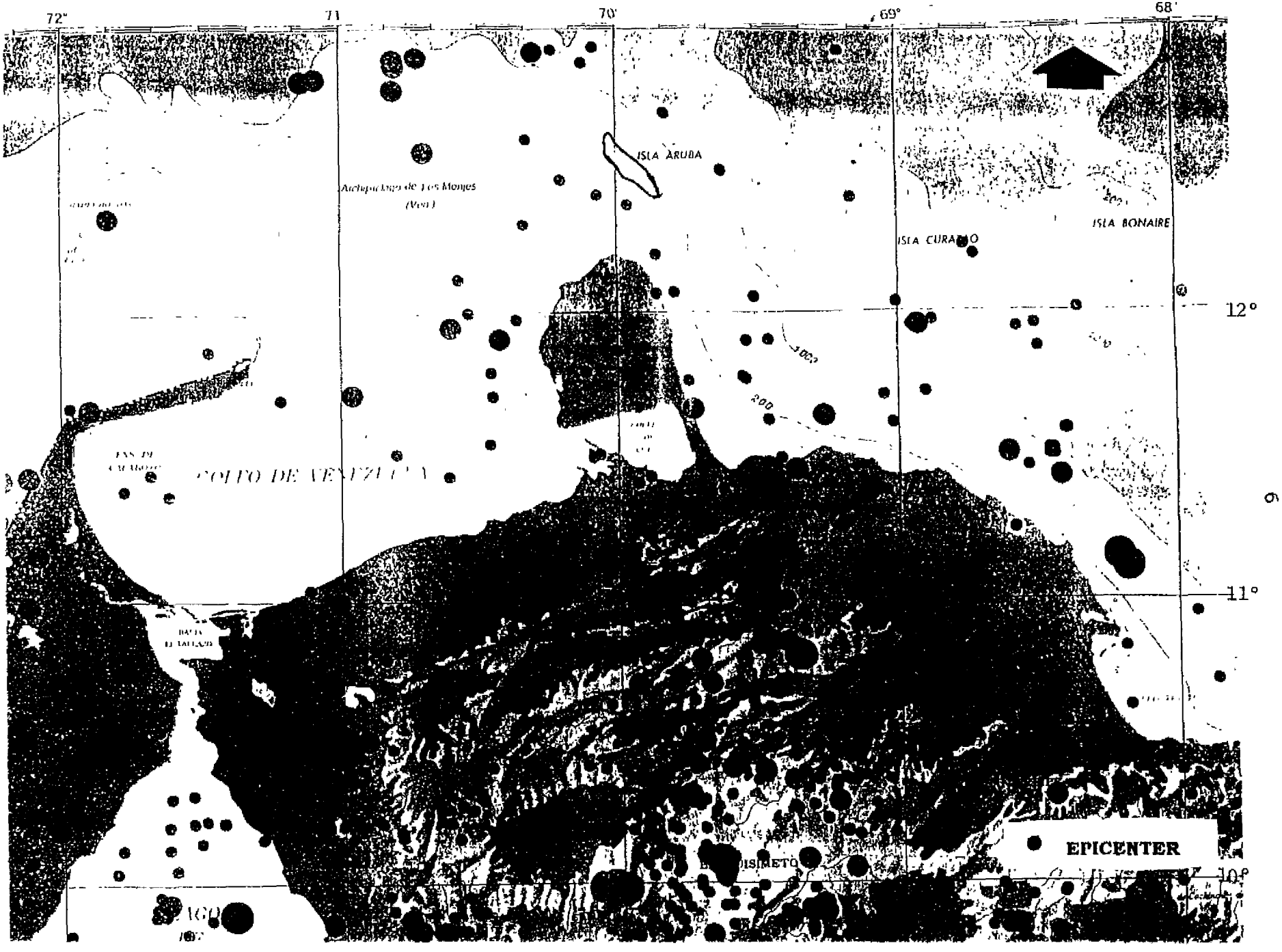



**FIGURE 3 Seismicity Map of North-Western Venezuela (Funvisis, 1997)**

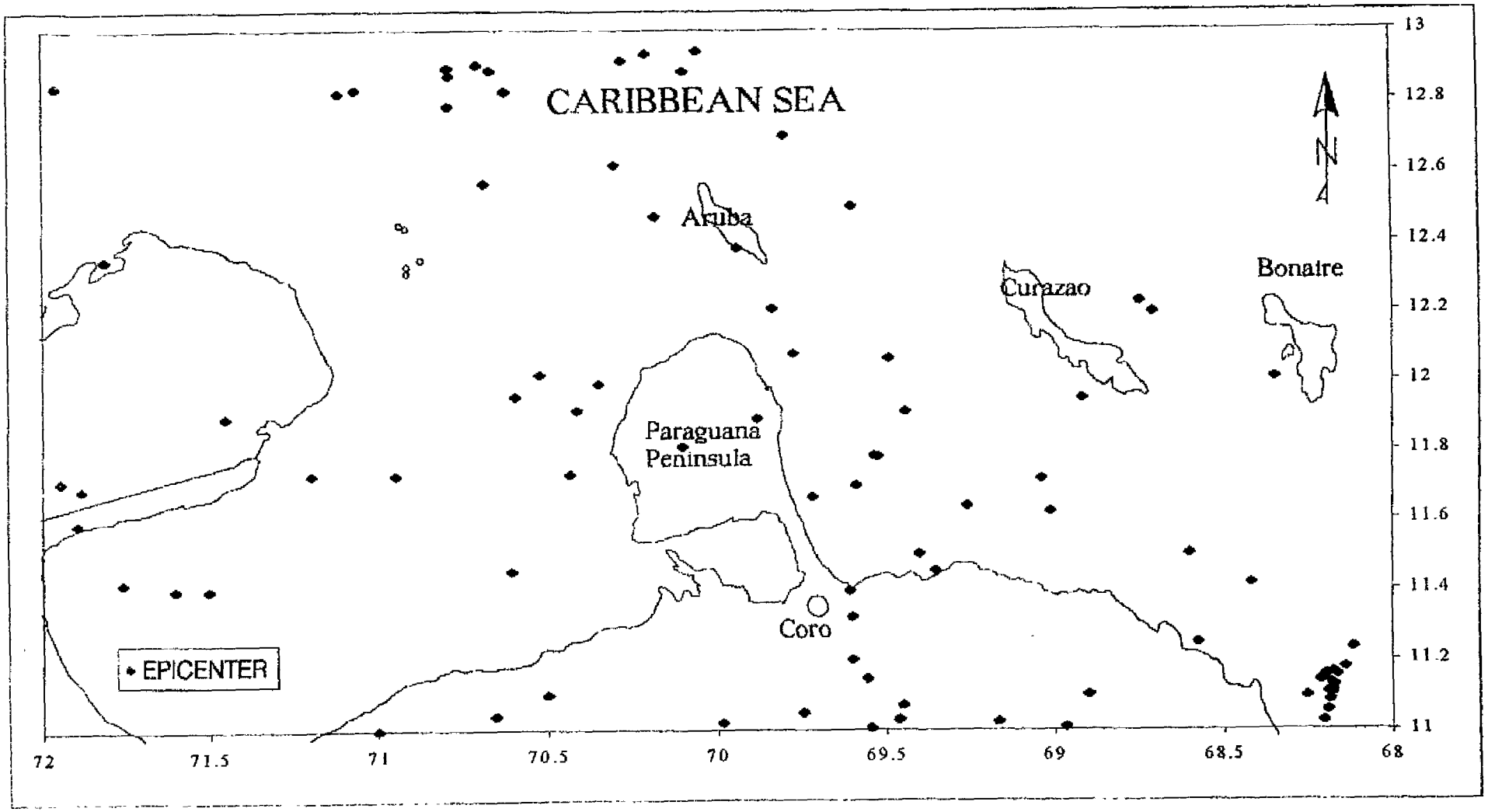



**FIGURE 4 Seismic Activity in the 1960-1996 Period (M ≥ 3,5)**

**4.1.3.- Seismic Hazard**

There are no known published studies indicating the level of seismic hazard of the Aruba Island. Nevertheless, due to its proximity to Venezuela we will use the Map of Seismic Zoning of Venezuela (COVENIN, 1987), to estimate the level of hazard. In this map the Paraguana Peninsula, some 30 km afar, is enclosed by the seismic zone 2 which prescribes a ground peak acceleration of 0.15 g, and a return period of 475 years (Figure 5). Therefore, it is assumed that Aruba has a seismic zoning similar to the Paraguana Peninsula. In addition, the venezuelan seismic code establishes a coefficient of use $\alpha$ equal to 1.25 for all structures of essential nature like hospitals, schools and public buildings. Therefore, for the seismic analysis of the Oduber hospital, a ground peak acceleration $A_o$ equal to 0.19 g must be taken.

**4.2.- Tsunamis**

Tsunamis are sea waves of long wavelength produced by the vertical displacement of the sea bottom during earthquakes. The wave height of a tsunami differs greatly according to the characteristics of the coastline and of the sea bottom. Places with smooth coastlines and deep sea will not favor large waves, while on coasts with irregular shorelines and shallow seas, the waves will be unusually high. Historically, no tsunami has been reported in Aruba, nor it has been in the coast of the Falcon State; however, because Aruba is an island in a zone of middle seismicity, it is not unlikely that it could be affected sometime by a tsunami, although that probability is low.

**4.3.- Hurricanes**

Most of hurricanes and tropical storms follow a trajectory farther north of the Netherlands Antilles; for this reason the probability that hurricanes affect the island is rather low.

**4.4.- Floods**

Statistics concerning the occurrence of floods in Aruba were not available. However, the hospital is seated in a plane area, almost at sea level, therefore it is susceptible of suffering floods. In such a sense, measures of low cost/benefit should be taken (for example, drainage maintenance) to prevent the effects of this natural hazard.

**4.5.- Other Hazards**

Other evaluated natural hazards are the following ones:

(i) Landslides: The hospital is located in a plane area, hence, there is any risk of this kind.
(ii) Volcanoes: The island of Aruba is not a volcanic zone.

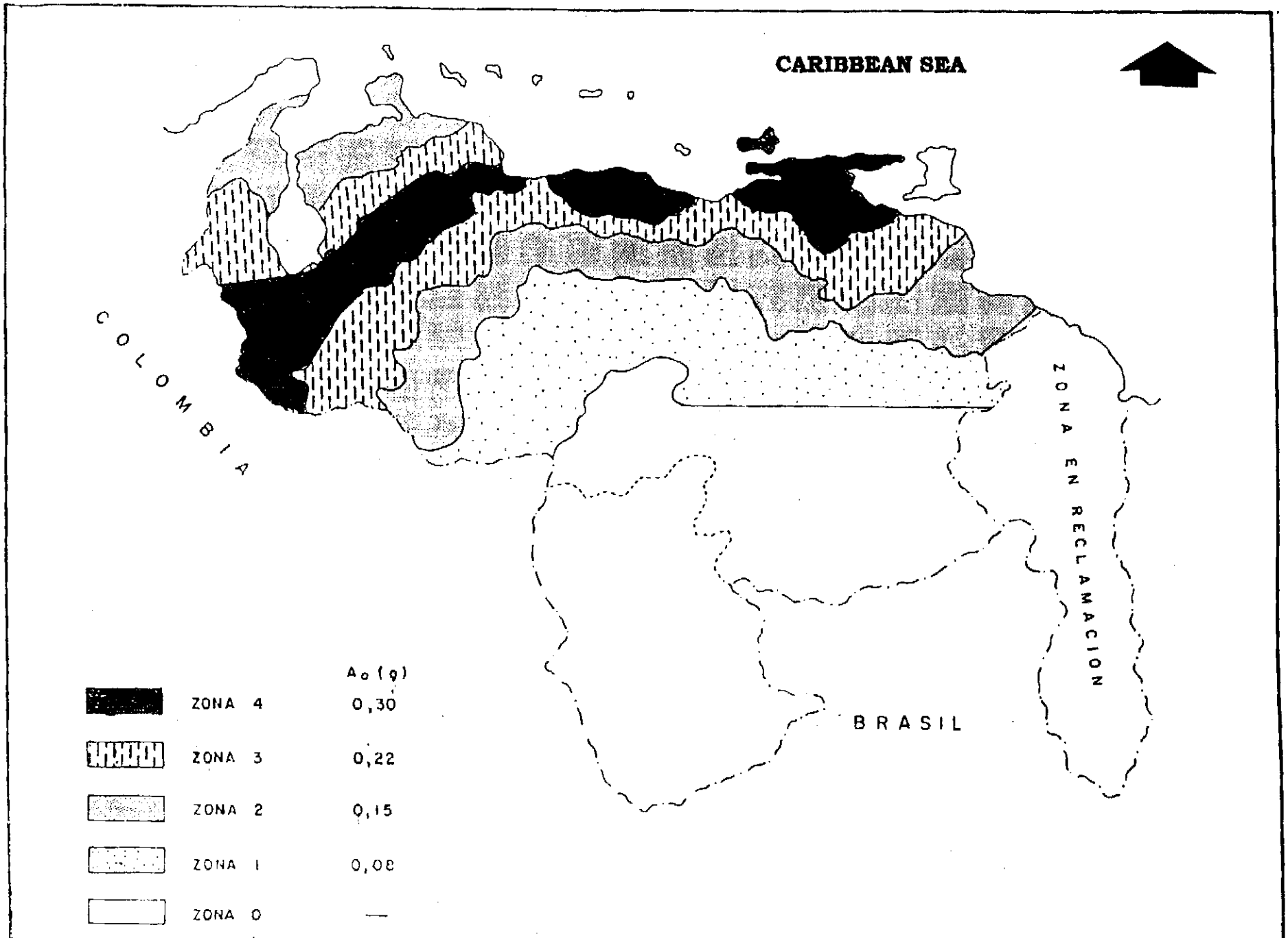



**FIGURE 5 Seismic Zoning Map of COVENIN Code 1756-87**

## 5.- HOSPITAL INFLUNCE AREA

The hospital was designed in 1973 (Algemeen zeikenhuis Aruba, 1973) and it has been provided with all the basic medical services, such as: general medicine, obstetrics, laboratories, surgery, pediatrics and hospitalization, as well as medical clinics.

This is the only hospital that exists in the island and for that reason its influence area covers the whole island, whose population was estimated in 93.000 inhabitants for 1998.

## 6.- GENERAL HOSPITAL DESCRIPTION

The hospital is located in the southwestern part of Oranjestad city, capital of the Aruba Island; it is some 800 meters from the coastline (Photo 2). In the Figure 6 appears the relative location of the hospital.

### 6.1.- Identification

Address: L. G. Smith Boulevard z/u, Oranjestad, Aruba
Telephone number: (297-8) 74-300
Fax number: (297-8) 73-348
Project design year: 1973
Construction year: 1975
Project memory: not available
Project drawings: not available
Director: Dr. P. Ho-Kang-You
Interviewed people:
Engineer F. P. Tromp, Head of the Technical Department
Mr. Jose Luis Koch, Technical Department
Mr. Eddy Van Las, Technical Department

### 6.2.- Description of the Hospital

The hospital is conformed by a group of buildings: one main of 6 levels and 8 annexes of 1 and 2 levels (Figure 7). Additionally, auxiliary buildings exist as apartments for visitors.

#### 6.2.1.- Main Building

It is a construction of reinforced concrete in a rectangular plan of 6 levels (Photo 3). This building houses the main medical services of the hospital: general medicine, hospitalization, maternity, pediatrics, etc. The hospital has three entrances: the main entrance is at the front facade, another is in one side and a third is at the rear. The main entrance is found in the Annexed A building (see Figure 7), between the Cafeteria and the Administration.

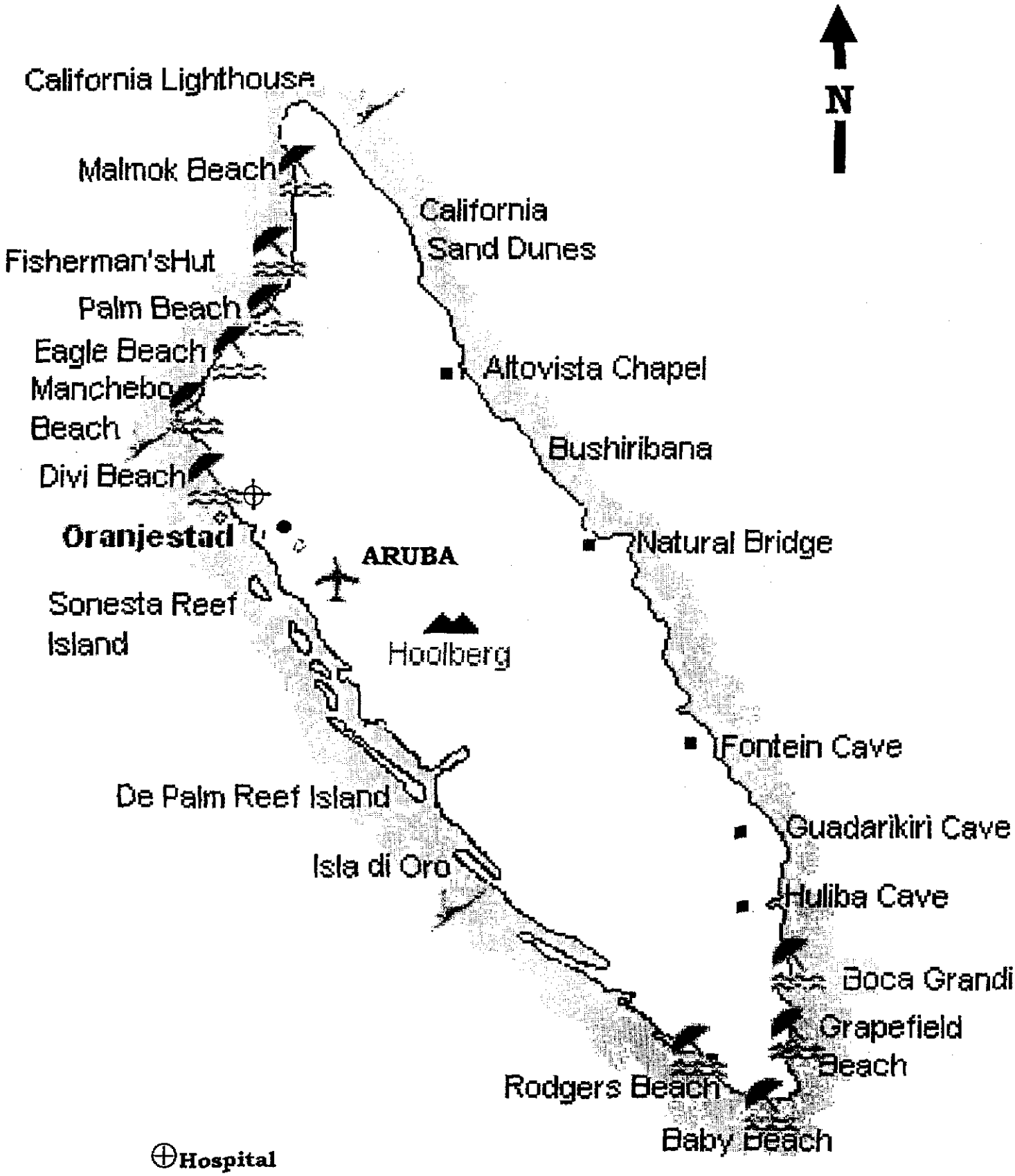



**FIGURE 6 Relative Location of the Hospital**

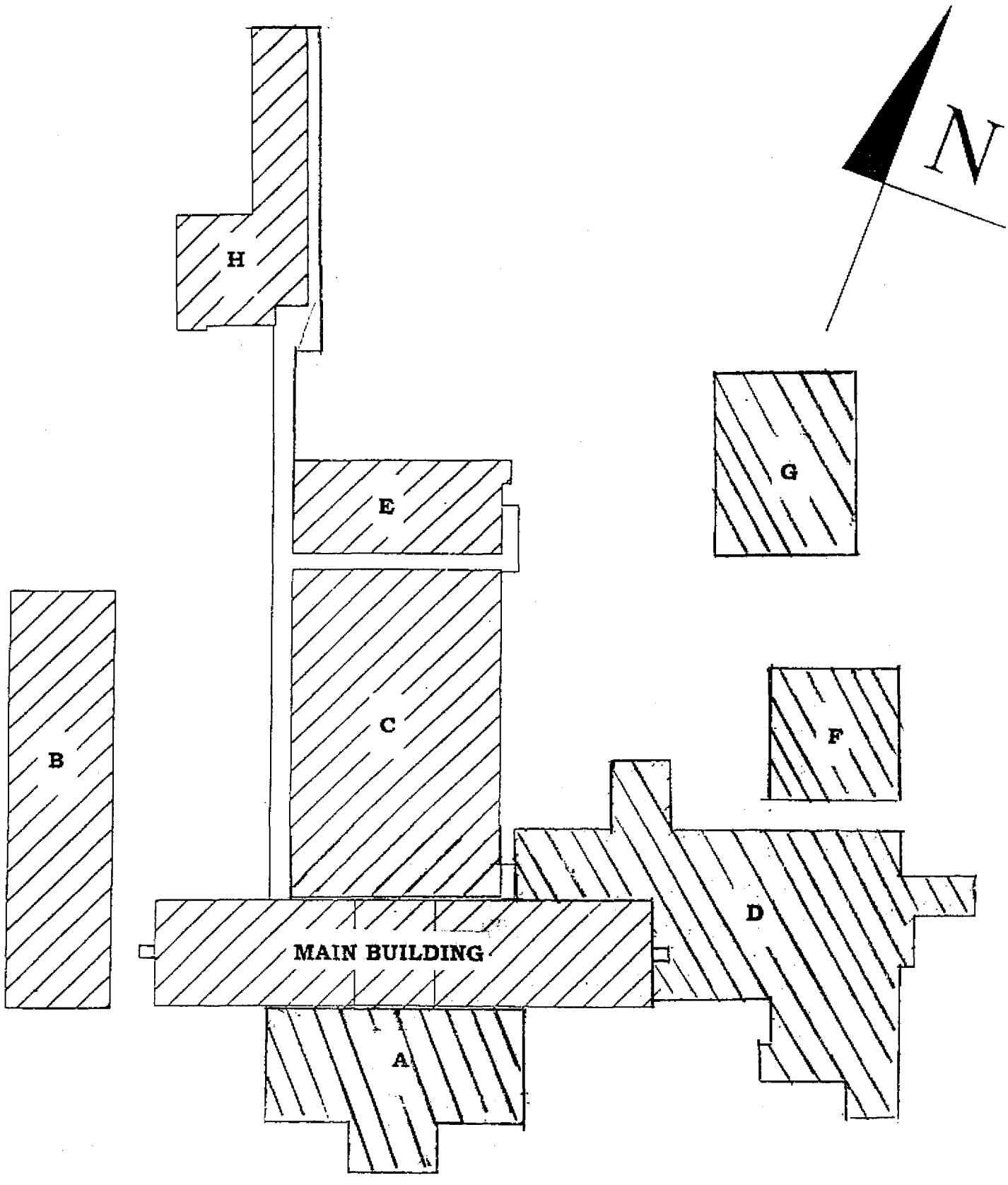



**FIGURE 7 Layout of the Hospital Buildings (scaleless)**

**6.2.2.- Annexed buildings**

The Complex Hospital is composed by 8 annexed buildings of reinforced concrete, seven of just one level and one of two levels, (see Figure 7). The Annexed buildings of one level are the following:

Annex A: Administration and Cafeteria
Annex B: Technical Department and Laundry
Annex D: Physiotherapy and Medical Clinics (Photo 4)
Annex E: Warehouse
Annex F: Bank of Blood (Photo 5)
Annex G: Psychiatry
Annex H: Auditorium

The Annex C, which has two floors, lodges the services of Surgery, Laboratories, X-rays and Morgue; this building communicates with the Main Building at the level of the first floor in the Surgery area (Photo 6).

**6.2.3.- Auxiliary Buildings**

The hospital has auxiliary buildings located in the rear part of its land plot (see Photo 2). One of those buildings is of 2 floors and it is used as office in the lower level and visitors' residence (patient, doctors and workers) in the upper level.

## 7.- ORGANIZATION, ACTIVE PERSONNEL AND PATIENT CAPACITY

**7.1.- Organization**

The hospital works like a private company, but it receives the government's contributions as a compensation for the services it provides to the community of the island.

The organizational line is headed by a Director, who is followed by its assistants and the heads of the different departments of the hospital.

Emergency and/or contingency plans:

(i) the hospital has organized a radio communication system with its employees so that they can report immediately in the event of emergency
(ii) they carry out emergency exercises, with certain frequency, for the eventual occurrence of an air-crash
(iii) they have plans for cases of emergency but they have not carried out emergency exercises in the last two years
(iv) they have organized committees of civil defense in agreement with the firemen of the island.

**7.2.- Active Personnel of the Hospital**

The total number of employees is of 740, 44 of which are medical, 75 paramedics and 620 workers; at night hours it is considered that the personnel on duty is about 120 people considering doctors, paramedics and workers; the number of available beds is of 280.

**7.3.- Patient Capacity**

In average, the monthly total of assisted patients is of about 8.000, including hospitalization, emergencies and external consultations. The biggest affluence of people occurs during the days of visit, that is from Monday to Friday in the schedule from 11 a.m. to 1 p.m. and of 5 to 8 p.m.

## 8.- SITE, SERVICES AND LOCAL HAZARDS

**8.1.- Place**

The hospital is located in an flat area almost at the sea level and at a distance of some 800 meters of the coastal line. The relative location of the hospital is shown in the Figure 6.

The hospital can be accessed by three different roads; the Aruba International Airport is located about 5 km from the hospital (10 minutes in automobile).

**8.2.- Services**

- Potable water: the water is pumped by a hydroneumatic system from underground tanks; the hospital has three pumps, 2 in permanent service and the other one is kept in stand by.
- Sewage water: They drain into the Oranjestad sewers network. The inner network of served water pipes of the hospital hung from the roof and are underhanded with false roofs in Main Building.

**8.3.- Local Hazards**

* Earthquakes: see Section 4.1
* Tsunamis: see Section 4.2
* Hurricanes: see Section 4.3
* Floods: see Section 4.4
* Other hazards: Section 4.5
* Water dams: there is no water dam nearby

Technological risks: a refinery of petroleum exists in the Southeastern end of the island. According to the information obtained in the place, the gases emanating from the refinery move in a Southwest

direction, towards the sea, which is the reason why the related risk for the hospital is low.

## 9.- ELECTRIC, MECHANICAL AND SUPPLY SERVICES

### 9.1.- Electric Service

The service of light is provided by the national company of electricity of Aruba. The electricity control panels of the hospital is well installed.

### 9.2.- Mechanical Services

* Boilers: the elements of support of the boilers are metallic beams that rest on a base of concrete anchorage and are considered appropriate.
* Elevators: the main building has 4 elevators.
* Air conditioning: the main building is fed by a central system whose compressor is well anchored (Photo 7); in other areas of the hospital they have settled individual systems.
* Illumination: the system of illumination of the hospital complex is good and has a good maintenance service.

### 9.3.- Services of Supplies

* Kitchen: it is located in the lower level of the main building; it is a wide area with a good maintenance.
* Pharmacy: it is located in the ground level of the Main Building; shelves for medicines are generally anchored to the wall, some of them are not (Photo 8)
* Warehouse: the general storage is located the Annex E; its shelves are not anchored, but their eventual fall does not represent any serious risk for the hospital.
* Oxygen: the tank of oxygen (Photo 9) is located near the warehouse (Annex E); it has a capacity for 6.000 gallons and is anchored to its base with three fasteners; the oxygen for emergency is supplied by a group of interconnected gas gvessels that are tied to each other (Photo 10).
* Medical Histories: they are kept in mobile filers and shelves at the Auditorium (Annex H); the shelves are not anchored (Photo 11)
* Emergency Power Plants: the hospital has two power plants for emergency of 350 kw each one. They are well anchored and they are tested every 2 weeks.

## 10.- BUILDINGS STRUCTURES CHARACTERISTICS

The hospital complex Dr. Oduber is conformed by a Main Building, 8 Annexes and the auxiliary buildings, as indicated in Section 6. In this section a qualitative evaluation of the Main Building and a general view of the Annexes is to be made.

### 10.1.- Main Building

It is a reinforced concrete structure of 6 levels in a rectangular plan with flat plates 20 cm of thick. In the transversal direction, it has 12 resistance lines with 4 columns each one plus 2 walls 20 cm thick and in the longitudinal direction has 4 resistance lines with 12 columns each one (Figure 8).

The columns are rectangular varying with height dimension as verified in site; for example, the columns of the axis A have in the ground level dimensions of 46 x 64 cm and in the level 5, 45 x 51 cm.

Figure 9 shows the building elevation, in which one can see that the level 6 has a smaller area (also see Photos 3 and 6).

In the **Appendix A** a simplified preliminary analysis of the building is presented, and it is concluded that the this building should be reinforced to assure an appropriate seismic behavior.

Other elements of information for the evaluation of this building are:

* Roof: it is a concrete flat plate without a water tank. Risks of parapets fall were not identified ( Photo 12)
* Vertical Configuration: it is of a regular type, since it does not show any entering nor any salient in all the height
* Horizontal Configuration: it is a rectangular and approximately symmetrical plan in transversal direction (see Figure 8)
* Windows: they are of the swinging type (Photo 13)
* Short columns: no short column condition was observed
* Facades: the East and West facades are provided with parasols (see Photo 12)
* Walls: the walls are of concrete hollow blocks (Photo 14)
* Floors: they are made of granite in the levels 1 at 5 and of ceramic in the ground level.

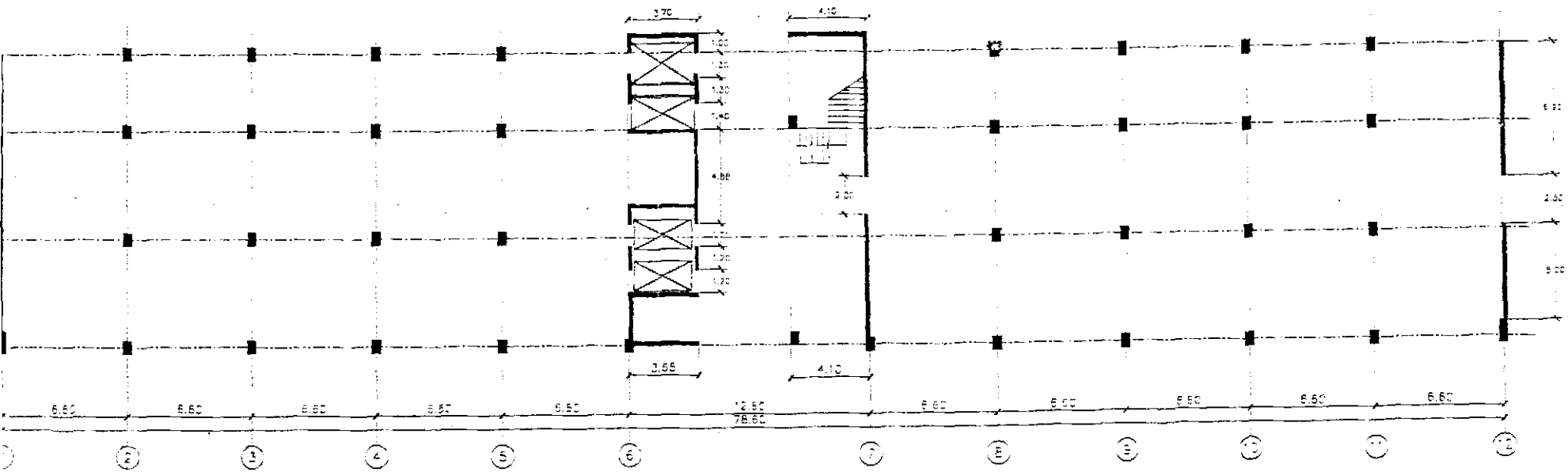
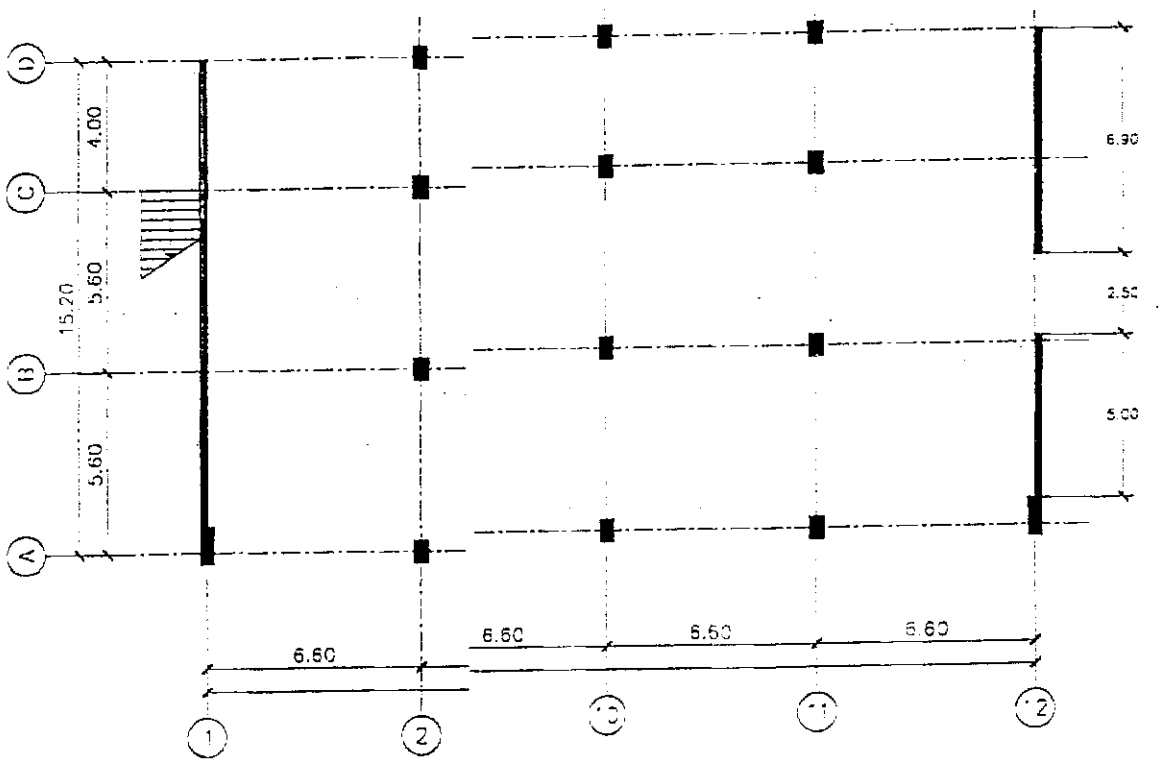


FIGURE 8 Layout of the Main Building of the Hospital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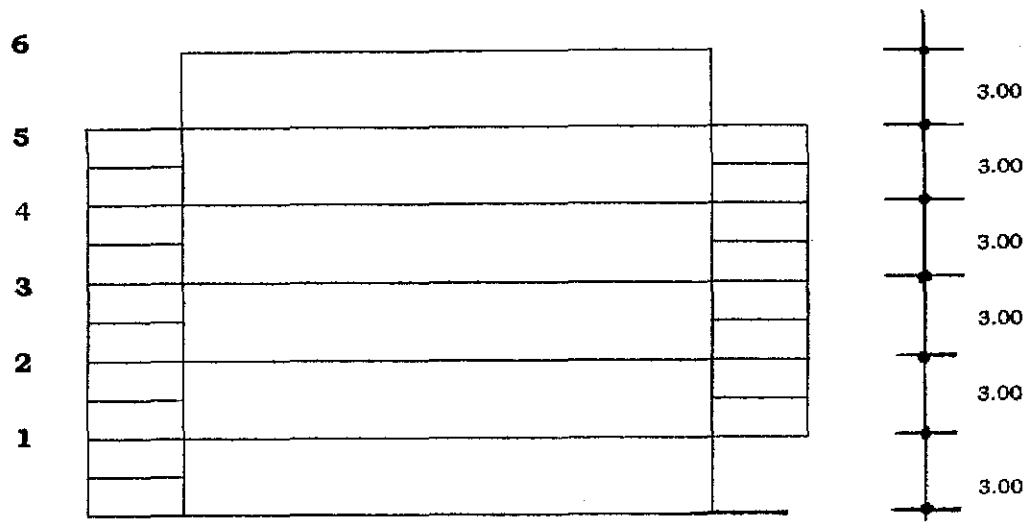


**FIGURE 9 Elevation view of Main Building**

* Corrosion: no sign of corrosion was detected in the structural elements
* Soil Studies: no soil report of the area of the hospital was available
* Foundations: according to the information got in place, the building has direct foundations.
* Stairways: the building has three stairways, one central and two lateral. The central one is metallic with wooden steps, covered with aluminum rails; its width is of 1.50m. The lateral stairways have a width of 1.15m and are in the Eastern and Western building facades; this stairways are of concrete and have metal fences that show corrosion signs visible at several floor levels (Photos 15 and 16); likewise, some corrosion signs were detected in the concrete slab of some stair steps.

In general the state of the building is in a fine condition due to a good maintenance service

**10.2.- Annexed Buildings**

In general the structure of the Annexes is conformed by roof slabs and columns of reinforced concrete and either metallic or reinforced concrete beams.

In the inspection visit made to these buildings, elements presenting a high vulnerability to earthquakes, like short columns and parapets, were not identified.

## 11.- FIRE HAZARD AND PREVENTIVE ACTIONS

* There are not smoke detection systems
* There are fire extinguishers in all the floors
* There is insurance coverage against fire risks
* There is a protection system against rays from electric storms

## 12.- EVACUATION ROUTES

* There is no sign of evacuation or escape routes, for cases of emergency
* The exit doors are sufficiently wide and there are also wide spaces for the free people circulation
* The building have two lateral stairways for cases of evacuation in the eastern (Photo 17) and western (Photo 18) sides. The stairway of the Eastern side does not reach the ground level (see Photo 6) and people have to walk their way out over the roof of Annex D, and then go down through a metallic ladder

## 13.- EMERGENCY PREVISIONS

* Contingency Plans: the hospital has contingency plans for cases of emergency, but they have not been activated lately
* Alarm Systems: not installed at present
* Emergency Lights: they are installed and checked periodically
* Extinguishers: they are placed in all the floors and they are checked once a year
* Emergency Power Plant: there are two emergency power plants; additionally, the operating theaters have emergency battery systems with up to 8 hours service duration
* Smoke detection system: it is not currently at work

## 14.- VULNERABILITY EVALUATION RESULTS

Earthquakes, tsunamis and floods are the natural hazards that can affect the Hospital Dr Horacio Oduber due to frequency and intensity of these hazards in the zone where the hospital is located. In that sense, the resulting qualitative evaluation of the hospital complex, based upon the compiled information and the site inspection, can be summarized as follows:

i.- The seismic solicitations in the Main Building, preliminarily evaluated according to the COVENIN Seismic Design Code 1756-87, exceed the load capacity of columns at the ground level
ii.- The Annexes do not appeared to have major seismic risk
iii.- The probability of occurrence of a tsunamis is low, but it is necessary to make studies of the coast and the sea bottom, in order to assess the level of this hazard
iv.- The flood hazard in the hospital area is a risk whose level must be determined in face of its location in a flat coastal zone. Therefore, hydrological data should be analyzed
v.- The Hospital Contingency Plan is not adequately managed and, besides, the evacuation routes of the buildings are not signaled
vi.- The emergency stairways show some corrosion signs

## 15.- RECOMMENDATIONS

Because the Oduber hospital is the only one hospital in the Aruba island, it is of paramount importance to guarantee a good operating capacity, even during the eventual occurrence of earthquakes, tsunamis and/or floods. In this respect, the following recommendations are to be carried out in the short term:

i.- Get information of the structural project of the Main Building and the Annexes
ii.- Get information of relevant soil studies in the hospital area
iii.- Get hydrological data and historical antecedents of past floods in the island, if any
iv.- Make studies of the coast and the sea bottom to determine the level of tsunami risk
v.- Carry out a quantitative analysis of the Main Building in order to determine its reinforcement requirement
vi.- Evaluate the seismic behavior of the Annexes to determine any reinforcement requirement
vii.- Establish inspection program of the hospital drainage system
viii.- Fix all shelves and gas vessels
ix.- Repair the emergency stairways
x.- Evaluate an alternative to change the escape route for the eastern emergency stairway as it reaches the ground floor level
xi.- Activate contingency plans and install supporting system for emergency cases
xii.- Indicate the emergency escape routes in all buildings

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