2.4 Other Hazards

2.4.1 Torrential Rains

Although hurricanes are often accompanied by heavy rains, severe rainfall events are also associated with troughs and tropical depressions. The risk of flooding is therefore not restricted to, nor more likely to occur during, hurricane events

Drainage systems and structures in Grenada are generally designed for rainfall events having return periods of 20 years. This means that such systems are likely to become overloaded and cause some degree of flooding when rainstorms are experienced with return periods greater than 20 years.

Generally, lower lying areas will be more susceptible to flooding than higher and sloping ground.

The damage caused by flooding depends on the type and elevation of facilities in the location. The results of flooding may range from the inconvenience of temporarily submerged driveways to the loss of equipment and finishes inside flooded buildings and consequential disruption of the functions.

2.4.2 Volcanic Activity

Grenada has the only known submarine volcano (Kick 'em Jenny) in the region. It is located just north of mainland Grenada. The first recorded eruption reportedly occurred in 1939. Studies dating back to 1972 indicate that minor eruptions have been occurring on a fairly regular basis and that the summit of the volcano is growing at a rate of approximately 4 meters (13 feet) per annum.

The potential hazard of Kick 'em Jenny to Grenada and the rest of the Eastern Caribbean lies in the form of tsunamis, should a major under water volcanic eruption occur.

A tsunami (or seismic sea wave or tidal wave) is a series of ocean waves generated by any large-scale, short-duration disturbance of the free surface of the ocean. The majority are related to tectonic displacements associated with earthquakes at plate boundaries. However, tsunamis can also be generated by erupting volcanos, landslides or underwater explosions. In the open ocean, tsunamis may have wavelengths of up to several hundred miles but heights of less than 1 meter (3 feet). Because this ratio is so large, tsunamis can go undetected until they approach shallow waters along a coast. Their height as they crash upon the shore mostly depends on the geometry of the submarine topography offshore, but they can be as high as 30 meters (100 feet).

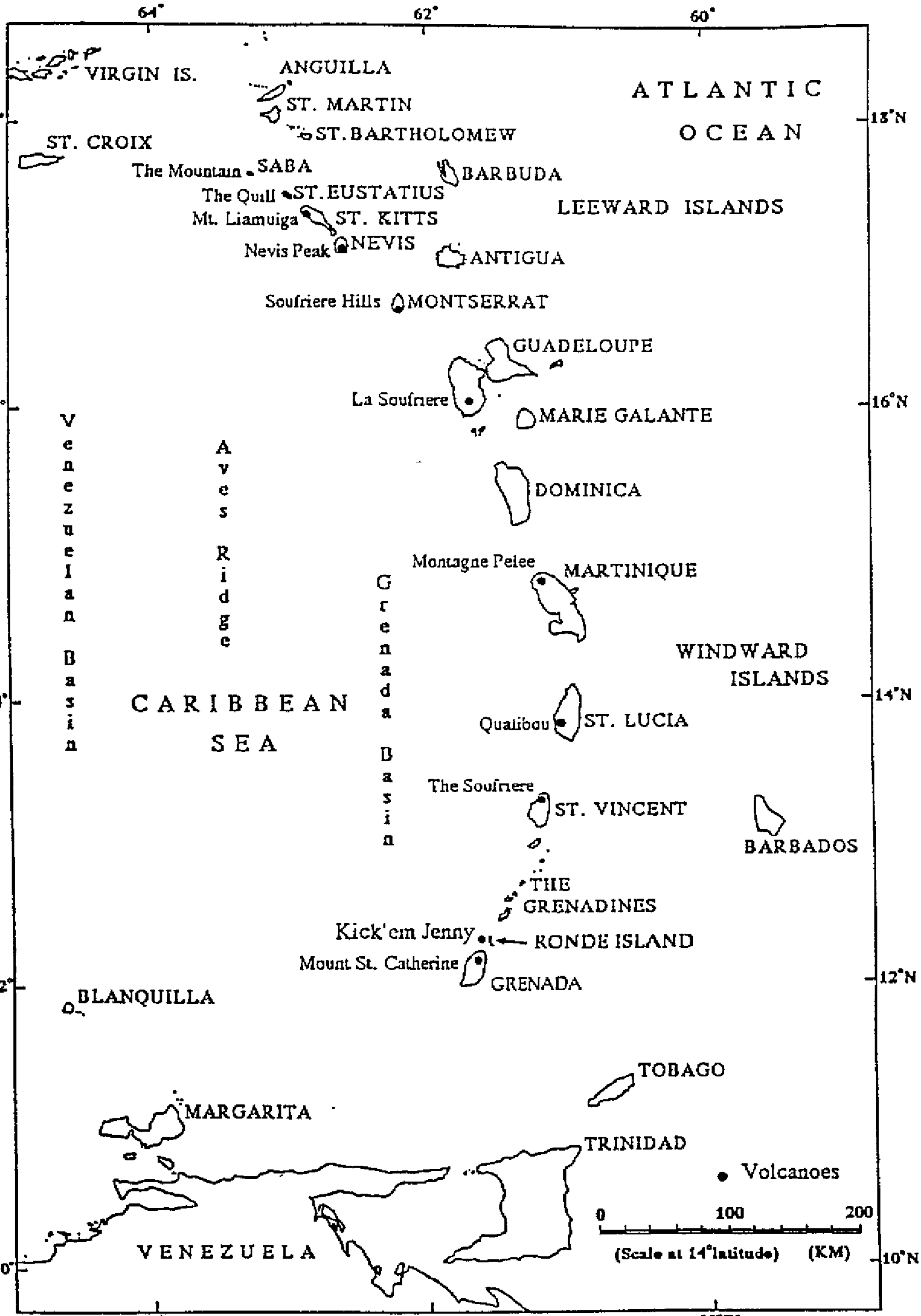
A tsunami travels at the speed of sound, 1100 feet per second (750 mph). Therefore, within one hour of an occurrence at Kick 'em Jenny, most of the islands of the Eastern Caribbean will be affected.

Figure 12 shows the locations of volcanic centers in the Lesser Antilles. Figure 13 indicates the travel times from Kick 'em Jenny and figure 11 gives the wave heights at the various islands resulting from a "realistic" scenario for a volcanic event at Kick 'em Jenny.

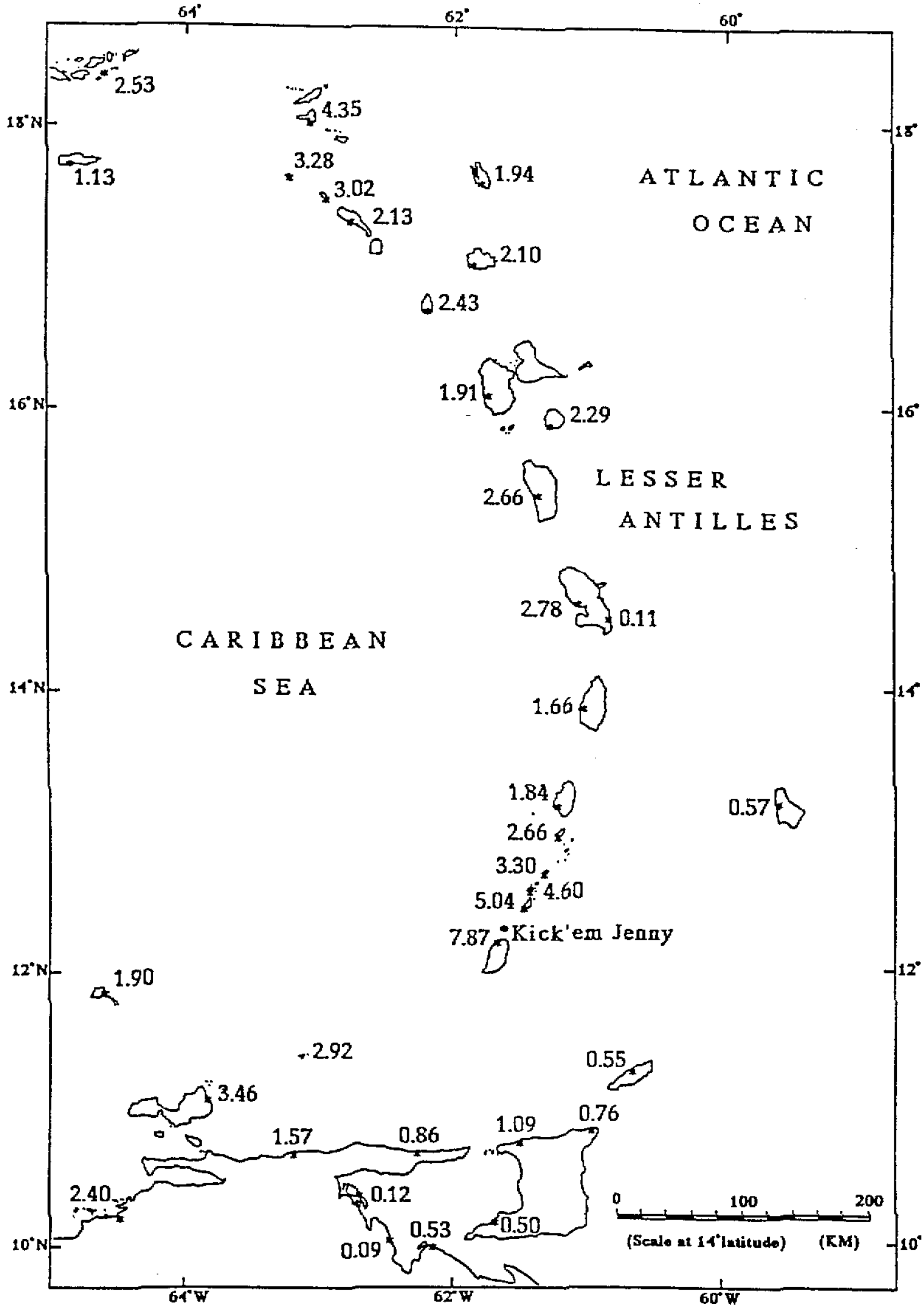
It has to be said, happily, that tsunamis from Kick 'em Jenny or other sources do not pose threats for the hospital because of its height above sea level.

The pages following pages contain the following figures:

Fig 12	Location of Main Volcanic Centres in the Lesser Antilles
Fig 13	Run-up Values for Tsunamis for a "realistic" Kick 'em Jenny Event



Outline map of the Lesser Antilles
showing locations of main volcanic centres
(Martin S Smith and John Shepherd, Dec 1992)



Final run-up values in metres for a 'realistic' scenario event at Kick'em Jenny (VEI = 3) (Martin S Smith and John Shepherd, Dec 1992)

3. INVESTIGATION PROCEDURE

3.1 General

The hospital facility comprises 12 clearly identifiable buildings. The disposition of these buildings is shown on the site layout in Appendix B. The main hub of the facility can be further separated into several distinct units and, for the purposes of this report, these units will be treated as individual entities where applicable. The following is a list of the identifiable units. The numbering system used hereunder is the same as shown on the site layout.

Building Number	Building Name and/or Function
1	Reception & Administration; Duncan Ward & Nursing School (on upper floor)
2	Mortuary
3	Canteen/Records
4	Bridge
5	Laboratory
6	X-Ray & Casualty; Administrative Offices (on upper floor)
7	Sanitary Annexes
8	Male Wards; Female Wards & Maternity Ward (on upper floor)
9	Pediatric Ward
10	Sterilization Unit; Operating Theatre (on upper floor)
11	Doctor's (On-Call) Residence
12	Kitchen
13	Private Ward
14	Generator; Incinerator & Electrical Switching
15	Nurses Residences
16	Psychiatric Ward
17	Eye Clinic

No drawings of any of the buildings are available and therefore all the information presented here was obtained through on-site observations and discussions with hospital personnel.

A programme of repairs is currently being undertaken and includes work to the Private Ward, the Kitchen and parts of the Main Building.

3.2 Desk Studies

3.2.1 Earthquake-resistant Design

There are a number of guidelines which can be followed to ensure that buildings and ancillary items offer the best possible resistance to earthquakes. Although deviation from the following rules will not necessarily result in an unsafe building, the basic principles are well grounded. Ideally, buildings should be:

- symmetrical;
- not too elongated in plan (length:width ratio <3);
- continuous and monolithic, with a uniform strength distribution;
- designed so that vertical members will remain intact after horizontal members have failed;
- designed so that columns and walls are continuous from foundations to roof.

Features such as projecting towers, abrupt changes in section of structural members and offset columns/beams should be avoided. Adjacent low-rise buildings should be constructed with 2-inch (minimum) gaps between them to allow for movement and to prevent battering.

Non-structural elements such as infill panels, windows, doors, suspended ceilings, services and fixtures also require careful consideration. Inappropriate detailing of stiff infill panels could lead to premature failure of surrounding structural elements and/or the panel itself.

Ground motion during an earthquake results principally in the generation of horizontal shear forces. It is these forces, and the resulting stresses, which structures must be designed to withstand. The magnitude of these stresses at any level of a building is directly related to the weight of the building above that level and the height of that level above ground. Thus taller and heavier buildings are, in general, more susceptible to earthquake forces than shorter and lighter ones.

Generally, the buildings comprising the facility are two storeys high, rectangular in plan without exceeding a length-to-width ratio of 3 and relatively symmetrical. These buildings are therefore conceptually more favourable for the resistance of earthquake forces

Most of the buildings, however, are susceptible to secondary damage from possible collapse of non-structural partition walls, falling over of free-standing storage shelves and cupboards, fracture of plumbing, air-conditioning and electrical lines, and possible breakage of windows and other glass panels.

3.2.2 Hurricane-resistant Design

Although there have been instances of block walls being blown over in hurricanes, adequately reinforced and tied panels have usually performed well. Of much greater concern are lightweight roof structures and unprotected doors and windows.
For lightweight roofs, the provision of hurricane straps and adequate holding-down details is of critical importance and roof sheeting of 24 gauge or greater thickness is desirable. The loss of a few roof sheets is not usually costly in terms of replacement. However, collateral damage to equipment and fittings inside the building by wind and rain can result in substantial losses. In addition, the temporary loss of use of a facility as important as the hospital can have a particularly negative effect on the community as a whole.

The overall vulnerability of the hospital to hurricanes is high because:

- except for those buildings currently under repair, the roof sheeting on all the buildings is in various stages of deterioration. In particular, the entire roof of the central core buildings needs to be replaced;

- external doors need to be replaced, strengthened and fitted with battens or otherwise secured;

- all windows need either to be or, in the short term, window openings should be protected with storm shutters.

3.3 Site Inspections and Meetings

Visits were made to the site on five separate occasions. On 17 July 1996

Mr Selwyn Woodroffe of CEP(Grenada) visited the site and met with the Hospital Administrator, Mr Douglas Andrews; the Chief Medical Officer, Dr Allan Budhlall and the Hospital Maintenance Supervisor, Mr Gregory Sandy. A brief familiarization tour of the compound was made to identify the individual parts of the overall facility. Subsequent detailed visits were made on 19 and 23 July. On both of these visits Mr Woodroffe was accompanied by Mr Sandy in order to gain easy entry into otherwise restricted areas. A further visit was made on 16 August 1996 to clarify certain information gathered on previous visits and on 17 and 18 August, a number of photographs were taken. On 12 September 1996 Mr Woodroffe and Mr Tony Gibbs of CEP(Barbados) made a further visit to the site and took more photographs.

A courtesy call was also made on 12 September 1996 by Mr Woodroffe and Mr Tony Gibbs to Ms Lana McPhail, Permanent Secretary in the Ministry of Health. Dr Bert Brathwaite of the Ministry of Health was also present at that meeting.

Inspections were limited to building superstructures and their ancillary fixtures, and to equipment vital to the maintenance of hospital operations. No examination of foundations was attempted and, in the absence of structural plans for the facility, reasonable assumptions regarding the current condition of the existing building structures must necessarily be made. It should be realized, however, that the type and condition of the foundations and the characteristics of the underlying soils will have a significant influence on the effects of earthquakes on the various buildings.

3.4 Buildings

Comments on the individual buildings are contained in the following sub-sections. As indicated in the introduction to this report, several of the building entities comprising the facility are connected and form a central core of the Hospital compound. For the purposes of the report, buildings 6, 7, 8 and 9 will be grouped as one and discussed under the heading "Building No.8 -- Male/Female Wards".

3.4.1 Building No.1 -- Reception/Administration/Duncan Ward/Nursing School

This is a two-storey, reinforced-concrete, framed building with infill external blockwalls. The first floor is of timber construction. The roof structure comprises trusses made up from 2-inch by 6-inch (2"x6") timber members spiked to a 2"x6" timber wall plate which is fixed to the reinforced concrete ring beam. Timber purlins are spaced at approximately 2-foot-6-inch (2'-6") centres, close boarded and covered with corrugated metal sheeting. There are signs of termite infestation in the timbers and some of the roof sheeting is in poor condition.

Although this building has been given an external face lift by painting, internally it is in a general state of disrepair. All the windows require proper shutters. Doors and door frames need to be strengthened and the doors should be fitted with barrel bolts or battens. The existing timber floor needs to be replaced.

The long-term solution would be to demolish the internal timber walls and partitions, and the timber first floor and rebuild inside the existing concrete frame (see photo 16).

3.4.2 Building No.2 -- Mortuary

This is a small, rectangular, one-storey building with a reinforced concrete frame and ground floor, block walls and a timber roof. The roof sheeting requires replacement and doors and windows require shutters and battens respectively (see photo 7).

3.4.3 Building No.3 -- Canteen/Records

This is a one storey building with a reinforced concrete ground floor, block walls and a timber roof. The roof requires replacement, the doors need to be secured with bolts or battens and the windows need shutters.

3.4.4 Building No.4 -- Bridge

This bridge provides a link between the Duncan Ward through the main wards to the operating theatre. It is made up of structural steel channel and angle sections forming a horizontal truss at floor level. The side walls are timber stud walls and timber rafters form the roof structure.

Under the action of high horizontal winds, this structure will be subjected to torsional forces because of a lack of stiffness at eaves level. A truss at eaves level, duplicating the one at floor level, will provide corrective stability against torsion (see photos 8, 9 and 10).

3.4.5 Building No.5 -- Laboratory

This is a two-storey, reinforced-concrete, framed building with infill blockwork panels. The vintage of this building suggests that the block panels are unreinforced. Over the years, a number of extensions have been made to the building. These extensions are basically concrete blockwork enclosures adjoining the original structure.

The original part of the building is covered with asbestos sheeting. Apart from the potentially hazardous nature of this material, asbestos sheeting is notoriously brittle and would be expected to fracture under the impact of flying debris. As expected, the roofs to the newer parts of the building are covered with corrugated metal sheets (see photo 2).

Replacement of the asbestos sheeting is recommended as a short term corrective measure.

3.4.6 Building No.6 -- **X**-Ray/Casualty

This is part of the central core and is discussed under Building No.8.

3.4.7 Building No.7 -- Sanitary Annexes

These are part of the central core and are discussed under Building No.8.

3.4.8 Building No.8 -- Male/Female Wards

Building No.8 (discussed here as one with Buildings 6, 7 & 9) is probably the oldest of the buildings on the compound. These buildings were originally used as barracks for Fort George. They later formed the original extent of the hospital.

It is basically a two-storey, masonry building with a timber first floor and a series of hipped, timber-trussed roofs over the various sections. These roof areas intersect at hips, valleys and ridges. Generally, all areas of the roof are steep sloped (>25°). However, the section of roofs over the pediatric ward (see photo 5) and maternity unit are quite shallow (<15°). Shallow-pitched roofs attract higher wind suction and this area will be more susceptible to damage by hurricane force winds

The roof sheeting over the entire central core (see photo 1) is generally in poor condition. Many of the fixings (drive screws or nails) are loose and are generally located at every fourth corrugation of the sheeting. Coupled with this is the fact that the purlins are also fairly widely spaced at approximately 4-foot centres. The main members of the roof trusses are of 12"x6" pitch pine, with 6"x4" secondary struts and ties

It is noted that the roof of this building is to be partially repaired under the current repair programme (see photo 14).

A new elevator shaft at the southern end of the building was constructed to replace the old one approximately ten years ago. However, the old shaft has not been demolished. Large cracks are visible in these old walls and at their junctions with the main building. This part of the existing structure currently poses a serious threat to the kitchen which is located to its immediate south. The demolition of this old elevator shaft should therefore be viewed as a requirement which is critical to the safety of the kitchen and other nearby facilities. Further investigations should, however, precede demolition of the old shaft in order to ensure that such demolition does not impair the integrity of the adjacent building structure (see photo 4).

3.4.9 Building No.9 -- Pediatric Ward

This is part of the central core and is discussed under Building No.8.

3.4.10 Building No.10 -- Operating Theatre/Sterilization Unit

The operating theatre is housed on the upper floor of a two-storey building adjoining the main core at its south-eastern corner. The upper floor forms a bridge over the main hospital driveway leading to the private ward, psychiatric ward and nurses' quarters to the south. The lower level to the west of the driveway houses the sterilization unit and, to the east, a new canteen is currently being constructed in the space which was previously used as a parking area for hospital vehicles.

A more recent structure than the central core, this building has a reinforced-concrete, framed structure with infill blockwall panels. The relatively open lower floor to the west would have rendered the building more susceptible to damage from earthquakes. However, the current introduction of blockwalls to form the new canteen at the lower level will significantly increase the stiffness at this level and therefore increase the resistance of the building to seismic forces (see photo 11). Both the first floor and the roof are of reinforced concrete construction. Airconditioning equipment and ducting is housed on the roof slab and is covered by a gable roof comprising simple timber rafters with timber purlins and corrugated metal sheeting for weather protection. This secondary covering structure is typified by widely spaced purlins and nailed sheeting connectors. As with the other buildings, this sheeting is not expected to perform well during a hurricane.

As with all the other buildings, windows require shutters and doors require strengthening and/or replacement.

3.4.11 Building No.11 -- Doctors' Residence

This is a relatively-small, two-storey, concrete-framed building used to house doctors on call. The building is in a completely dilapidated condition and will offer little resistance to hurricane force winds or earthquake forces. The building should be demolished and rebuilt (see photo 19).

3.4.12 Building No.12 -- Kitchen

This is a single-storey building with the usual timber roof structure covered with corrugated metal sheeting. The pitch of the roof, in contrast to most of the other buildings, is relatively shallow. Apparently, easy access to the roof together with its shallow pitch made it a good candidate for the installation of a solar water heating system. Inadequate fixing of the solar panels to the roof structure is in evidence. These panels could become dangerous missiles during a hurricane (see photo 4).

The entire roof structure of this building requires replacement. This is to be done under the current repair programme.

3.4.13 Building No.13 -- Private Ward

The private ward is of the same vintage as the central core buildings. This building is currently being repaired as part of the general repair programme. However, the roof sheeting has been replaced with 26-gauge corrugated metal sheets. This gauge is considered thinner than is desirable in hurricane conditions. Under these circumstances, the recommendation would be to double the number of fixings (i.e. halve their spacing) and therefore halve the magnitude of the applied force. This should be considered a short-term measure which should be reviewed over the longer term.

As with all the other buildings, windows require shutters and doors require strengthening and/or replacement.

Apart from the above defects, this building exhibits all the necessary characteristics that favour good hurricane (as well as earthquake) resistance. The roof is steeply sloped and hipped for good hurricane resistance. The plan shape of the building is rectangular (with a length-to-breadth ratio of less than 3), the walls are relatively thick, and the building is basically two storeys tall; thus exhibiting favourable concepts for good resistance to earthquake forces (see photos 17 and 18).

3.4.15 Building No.14 -- Generator/Incinerator/Electrical Switching

This building once housed the hospital laundry. Laundry facilities are now provided off the compound. The building is a simple shed comprising a concrete floor slab, block walls and timber gable roof. The fact that this building houses the standby generator and the switch gear makes it critical to the operation of the facility during and immediately after an event such as a hurricane. The structure of the building therefore needs to be looked at in its entirety with a view to effecting major strengthening. The dimensions of the building suggest that this could be done by constructing a new reinforced-concrete or structural-steel frame within the existing external walls. The roof of the building should be a reinforced concrete slab cast with a generous slope and suitably waterproofed. Windows and doors should be rebuilt and be provided with shutters (see photo 6).

3.4.16 Building No.15 -- Nurses' Residence

The Nurses' Residence is one of the older buildings of the hospital facility. It is a two storey masonry structure with a timber first floor and timber roof covered with metal sheets. The masonry external walls are generally 2'-0" thick. Internal partitions are timber and stop about 2'-0" short of the ceiling. The roof trusses, generally spanning about 24 feet, are made up from 2"x6" pitchpine and incorporating a roof pitch in excess of 25°. The roof has a dropped ceiling and is not close boarded. Purlins appear to be 1"x 8" timbers at approximately 4-foot centres.

This building is the second of only two which are covered by asbestos sheeting. For similar reasons as described in paragraph 3.4.5 it is recommended that this roof be replaced (see photo 21).

The disposition of the main masonry walls is favourable for the provision of adequate resistance to lateral forces generated by the design earthquake for Grenada. For hurricane force winds the critical items are the roof sheeting, doors and windows.

3.4.16 Building No.16 -- Psychiatric Ward

The most recently constructed building on the compound, the psychiatric ward appears to be well constructed in terms of its structural form and design. It is a reinforced concrete building with infill blockwalls and concrete floors. The roof structure is a timber truss with metal connections. The trusses appear to be adequately held down to the concrete ring beam.

The windows are aluminium louvres. However, these are not properly sealed around the frames and wind-driven rain enters through these spaces. The roof sheeting is of 26 gauge (24 gauge is preferred), **R**-profile, aluzinc material and the fixings are fitted with special washers which cover the full width of the ridge profile.

The external staircase landing at first floor is at the same level with the floor. This poses a constant source of worry for the staff and patients during the rainy season as water regularly flows under the main door during heavy rain.

3.4.17 Eye Clinic

This is a two-storey, reinforced-concrete, framed structure with infill blockwork panels. It was built within the past 15 years. Normal construction practice in recent times in Grenada leads to the presumption that the walls are reinforced and tied to the concrete frame. The roof structure comprises timber trusses with metal plate connectors. The quality of truss connections also leads to the presumption that the trusses are adequately tied down to the eaves-level ring beam. Purlins are, however, too widely spaced at approximately 4-foot centres and their nail fixings to rafters need to be strengthened.

As with all other buildings, the windows require shutters and the doors need to be made more secure.

3.5 Services and Utilities

The maintenance of reliable supplies of power and water and a functioning communications system are critical factors for the operation of an hospital during a hurricane and immediately after a hurricane or earthquake. The effective disposal of sewage is also an important factor in order to minimize the possibility of outbreaks of disease following disasters. The provision of internal backup supplies of water and power are therefore vital to the continuity of hospital operations, and will reduce the burden on public utilities, after a disaster.

3.5.1 Electrical Power

Most of the electrical power is carried through the compound via suspended cables supported by poles. These are very susceptible to hurricane damage from the force of wind, the branches of trees and from flying debris cutting wires, thereby making the compound dangerous for pedestrian traffic (see photos 27 and 28). In the short to medium term, these cables should be buried underground in adequately sized conduits.

It is reported that the standby generator is adequately sized to handle the current power requirements of the hospital. However, power from this unit is also carried via suspended cables. The burying of these cables should be viewed as a short-term requirement of much importance. In addition, the building housing the generator set and switch gear should be strengthened as indicated in the previous section of this report.

3.5.2 Water

The hospital has its own water-storage tank. It is located on the hill to the west of the compound and can therefore adequately gravity feed the entire hospital. The tank was constructed a long time ago (probably during the military use of Fort George in colonial times) and while its capacity is not known, it is reported that the hospital is never out of water (see photo 30).

Notwithstanding these reports, the age of the tank makes it important that the structure be investigated to ensure that its integrity is intact. Worth noting is the fact that there exists a steady trickle of water behind the relatively newly constructed eye clinic on the sloping ground below Fort George. The water authorities have been brought in to investigate the source of the ground water and they have determined that it is not the water storage tank.

3.5.3 Sewerage and Solid Waste Disposal

All sewage and grey water waste are disposed of through the hospital's connection to the St George's Sewerage System. Solid medical waste is consumed in the hospital's on-compound incinerator. Both systems are reported to be operating in a satisfactory manner. As indicated in section 3.4.15 of this report, however, the building housing the incinerator will require major strengthening because of the critical nature of equipment therein.

3.6 Communications

The maintenance of effective communication links during and after a disaster is most important if the hospital is to make the most effective use of its resources. This not only refers to telecommunications, but to the physical links between the buildings comprising the hospital facility. There are two main covered links *viz*:

- the bridge between Duncan Ward and the central core;
- the bridge between the Private Ward and the central core.

The latter is being reconstructed under the current repair programme. The former requires retrofitting as described in section 3.4.4 of this report.

The protection of electrical power lines by burying them has already been mentioned. This should also be extended to telecommunication lines. The various units of the hospital facility should also be linked by an internal intercom network. In addition, if this does not already exist, a wireless communications link should be established between the hospital Administration Centre and the National Emergency Relief Organization (NERO).

3.7 External Works

The roadway to the hospital is virtually a cul-de-sac. There is another very narrow road leading from Fort George to a point just north of the hospital compound proper. At the best of times, this road is extremely difficult for cars to negotiate, much more so for the vehicles which will require quick access into and exit from the compound in times of emergency (see photo 26).

The long-term solution for vehicular traffic to the present hospital site is the construction of an access road from the Carenage, behind the current Ministry of Health buildings. This should also be accompanied by the upgrading and widening of the present access road. The combination of these two actions will provide a through road for the compound.

The location of the hospital on the hillside is likely to prevent flooding from being a major problem. However, drainage works should be improved by the construction of proper, well-defined, drainage channels. Currently, the cross culvert at the entrance to the hospital compound is blocked (see photo 29). This should be cleared and investigations as to its adequacy of size be made with a view to improving its performance.

4 CONCLUSIONS & RECOMMENDATIONS

4.1 General

The hospital facilities are generally in poor condition. There is widespread evidence of inadequate maintenance and all the buildings are likely to suffer serious damage in a severe hurricane, through loss of their roofs and water damage through unsecured doors and windows. In its current state, it is unlikely that the hospital will be able to provide, efficiently or adequately, the services for which it will be required during and immediately after a major hurricane.

It is to be noted that much of the work being carried out under the current repair programme is of a purely cosmetic nature (the scope of work under this repair programme is listed in Appendix C). The work entails much painting, replacing of floor boards and replacing of ceiling boards. Where roofs are to be repaired or replaced, 26 gauge (normally locally available) aluzinc sheeting is being used, and no special attention is being given to the type of fixings or their spacing.

The observation on roof structures on the hospital buildings is that the trusses or rafters are generally adequately sized. The details of their holding down connections are not visible and could not be investigated within the scope of this exercise. The spacing of purlins and the fixing of roof sheeting thereto are in most cases too wide.

4.2 Short-term Measures

The following items should be implemented now:

- Hurricane straps should be fitted to all trusses and rafters where it appears that the holding down detail is suspect or where the detail is not visible (*eg* where it is encased in concrete or masonry).

- Roof sheeting should be replaced on all roofs other than those which are currently being replaced. 24-gauge sheeting should be used. Fixing spacing should be at every other corrugation generally, and at every corrugation at eaves, ridges, hips and gable ends. Fixings should be fitted with washers matching the profile of, and wide enough to cover, the ridge of the profile.

- Plywood sheets should be stored in an easily retrievable location to be used as window shutters for use in the short term. Each sheet should be cut to size and marked to identify its proposed window location for installation in the event of a hurricane warning.

- Install barrel bolts at the top and bottom inside face of all external doors.

- All large trees in the vicinity of buildings and utility poles and wires should be trimmed.

- The cross culvert at the entrance to the hospital compound should be cleared and the upstream end fitted with a removable welded mesh of ½-inch diameter steel bars to prevent future blockage of the culvert.

- After replacement of the roof to the kitchen, careful attention should be paid to the manner of re-fixing the existing solar-water-heating panels to the roof structure.

- Retrofit the bridge between Duncan Ward and the main core of the hospital as described earlier.

- The doctors' residence and its adjoining out-house should be demolished.

- The old lift shaft should be demolished. Investigations into the effect of this demolition on the main building structure are, however, an important prerequisite.

- All free-standing cupboards and shelves, particularly those containing medicines or other potentially hazardous materials should be properly fixed to walls or floors.

Sketch details showing proposals for retrofitting in the short term are presented in Appendix B.

4.3 Medium to Long-term Measures

The following items should be scheduled for implementation during the coming 5 years:

- A new entrance/exit, to/from the hospital, should be provided from the Carenage. The existing road to the hospital should also be upgraded as part of this exercise.

- All remaining, overhead utility lines (power and communication) should be buried and existing utility poles removed.

- The water-storage tank should be drained and cleaned. A thorough investigation into its structural integrity should also be carried out. It would be prudent at that time to apply a waterproof coating to the inside surface.

- Hurricane shutters should be fixed to all windows. They should hinged to sturdy frames and fitted with hooking devices which can allow them to remain open under normal circumstances but easy to close and bolt shut in advance of a hurricane.

5 COST ESTIMATES

5.1 Preambles

The estimates of cost, for the various proposed short term mitigation measures, given hereunder, are order-of-magnitude estimates and should not be considered as actual construction costs. It should be noted that many of the estimates given refer to items of work which cannot be accurately quantified within the scope of this assignment. The degree of accuracy of costs presented here is expected to be within ± 20% of the actual costs, barring any major unforeseen items.

5.2 Short-term Measures

The item numbers in the table on the following page refer to the same numbering system as in section 4.2 above.

Item	Description of the Work	Cost (est) (EC$)
1	**Hurricane Straps:** Twisted metal straps bolted to rafters or trusses and bolted to masonry wall or ring beam	18,000
2	**Roof Sheeting:** Remove existing deteriorated roof sheeting and replace with 24 gauge sheeting. Any rotted rafters, purlins or other timbers should also be replaced. Reduce the spacing of purlins by addition of new purlins between existing ones. Sheeting fixings to be fitted with cyclone type washers. Fixings to be every other corrugation, generally, and every corrugation at eaves, ridges, and gables. *Above applies to all buildings except:* o *Canteen/Records* o *Old Doctors' Residence* o *Kitchen (current repair programme)* o *Private Ward (current repair programme)* o *Nurses' Residence (repair in medium-to-long term)* o *Eye Clinic (repair in medium-to-long term)*	360,000
3	**Temporary Window Shutters:** Cut ½" thick plywood sheets to size to suit window openings; mark each cut sheet to identify its building and window. Store in dry, ventilated and easily retrievable location. *(all buildings)*	24,000
4	**Trees:** Trim overhanging branches of all large trees in close proximity to buildings, utility poles and utility wires. Provide additional cable stays to utility poles to increase their overall stability in hurricane conditions	10,000
5	**Cross Culvert:** Clean out cross culvert at entrance to hospital compound. Fit removable welded mesh comprising 1/2" diameter steel reinforcing bars at 6" centres (both ways) at the upstream end of culvert.	2,500
6	**Solar Panels:** Ensure that solar panel frames are securely fixed to structure of kitchen roof.	1,500
7	**Bridge (Duncan's Ward to Central Core):** Add horizontal steel truss (similar to that existing at floor level of bridge) at eaves' level of bridge.	30,000
8	**Doctors' Residence:** Demolish doctors' residence and adjoining out house.	6,000
9	**Old Lift Shaft:** Carefully demolish old elevator shaft. Investigate probable effect on main building structure, and take necessary precautions prior to demolition	10,000
10	**Cupboards & Shelves:** Secure all free standing cupboards and shelves to walls and floors. Add lips to open shelves. *(all buildings)*	6,000
11	**Doors:** Install barrel bolts at the top and bottom inside face of all external doors. *(all buildings)*	4,000
	Estimated Total Cost of Short Term Measures	**472,000**