

Initial Seismic Vulnerability Assessment  
of Equipment, Utilities,  
Architectural Shell and Contents  
at  
Paropakar Maternity and Women's Hospital  
Thapathali, Kathmandu, Nepal



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Prepared for the World Health Organization Regional Office for South-East Asia by

### **Acknowledgments**

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## **Executive Summary**

Paropakar Maternity and Women's Hospital, Thapathali, Kathmandu, popularly known as PRASUTI GRIHA, was established in 1959. It is a tertiary central hospital with 415 beds, of which 336 are allocated to inpatients in the departments of Obstetrics, Gynaecology, and Neonatal. The hospital is Kathmandu's main specialty centre for women's health, and provides essential care for women and newborn babies. The Advisory Group for the Nepal Risk Reduction Consortium (NRRC) Flagship Project 1, which is tasked with improving hospital earthquake safety in Nepal, identified Paropakar Maternity and Women's Hospital as having high priority for assessment due to the essential medical services it provides.

As part of the assessment process, GeoHazards International (GHI) sent a team to Kathmandu in May and June 2013 to assess the potential seismic vulnerabilities of building utility systems, equipment, architectural shell elements and contents (i.e., nonstructural elements) in Paropakar Hospital and two others, which are assessed separately. The seismic vulnerability assessment of equipment, utilities, architectural shell and contents complements a structural assessment and a functionality/emergency preparedness assessment being conducted by others as part of the larger project. The assessment is intended to provide the hospital, the Ministry of Health and South East Asian Regional Office (SEARO) of WHO with recommendations to improve the hospital's ability to deliver medical care following a major earthquake. The team obtained the information included in this report by conducting in-person evaluations of building contents and utility systems over several days at the hospital; reviewing available technical reports and drawings; holding discussions with the hospital administration and engineering, maintenance and medical staff; and obtaining technical information from the literature. This report presents the GHI evaluation team's findings and recommendations.

The hospital facility has numerous seismic vulnerabilities in its utility systems, equipment, architectural shell and contents, which should be addressed as part of a larger effort to improve the seismic performance and functionality of the facility. Results of the detailed structural assessments were not available at the time of this report but are of critical importance. Most of the hospital's buildings were built between the late 1950s and late 1970s, and are unlikely to contain the earthquake-resistant features required by modern building codes. The Old Block is of particular concern, because it is an old unreinforced brick masonry building, a type that is well known to be vulnerable to earthquakes, and also because it houses many of the hospital's critical medical services. Though structural assessment is outside GHI's scope for this project, GHI anticipates that the results of the structural assessments will indicate that some hospital buildings are likely to experience significant structural damage in a strong earthquake. This damage would affect the hospital's ability to provide medical care in the aftermath of a strong earthquake. GHI recommends that the hospital consider locating the most critical services in most structurally sound buildings, as determined by a detailed structural assessment.

Of the vulnerabilities in GHI's assessment scope, those in the electrical power system present the most serious threat to the hospital's post-earthquake function. GHI recommends that the hospital immediately take steps to seismically protect the backup electrical power system. The other immediate-priority recommendations include restraining medical gas cylinders against toppling,

providing backup communications capacity, repairing the non-operational fire suppression system, and ensuring that exit pathways are unlocked and clear of impediments.

The mitigation and preparedness measures necessary to help keep the hospital running after a major earthquake will take time to implement, and will need to be integrated with the overall seismic safety improvement plan, then planned and spread out over a number of years. Paropakar Maternity and Women's Hospital will then be much better prepared to serve the community following an earthquake.

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## **Background**

The Nepal Risk Reduction Consortium (NRRC) was established in May 2009 to emphasize the shift in focus of development assistance to a disaster risk reduction perspective. Out of five flagship projects under NRRC, Flagship Project 1 is “School and Hospital Safety-Structural and non-Structural aspects of making Schools and Hospitals Earthquake Resilient”. Currently, the World Health Organization (WHO) is coordinating the ‘Hospital Safety’ component of the Flagship 1 Project with the Ministry of Health and Population (MOHP) as the lead Government of Nepal agency. The Department for International Development, UK (DFID) is supporting a three-phase project “Improved Seismic Safety of Priority Hospitals in Nepal.”

An Advisory Group comprised of relevant Government of Nepal agencies, development partners, and other stakeholders was set up for Phases 1 and 2. Phase 1 includes rapid seismic vulnerability screening of 60 hospitals with more than 50-bed capacity. Phase 2 consists of more detailed structural, nonstructural and functional (i.e., preparedness) surveys of 20 hospitals, including six priority hospitals identified by the Advisory Group. The project also has a Phase 3, in which engineers will conduct detailed structural assessments and analyses, design seismic retrofits and estimate retrofit costs for 10 hospitals. Engineers will present retrofit recommendations and initial cost estimates at a donor conference at the end of 2013. WHO has engaged GeoHazards International (GHI) to assess the potential seismic vulnerabilities of nonstructural components in several priority hospitals as part of the Phase 2 survey. The Advisory Group identified the National Academy of Medical Sciences (Bir Hospital), along with Paropakar Maternity and Women's Hospital, the Kanti Childrens’ Hospital, and several others, as having high priority for assessment, due to the critical medical services they provide on a day-to-day basis.

Paropakar Maternity and Women's Hospital, Thapathali, Kathmandu, popularly known as PRASUTI GRIHA was established on August 1959. It is situated on the north bank of Bagmati River, near Thapathali Bridge, as Figure 1 shows. It is a tertiary central hospital with 415 beds, out of which 336 are allocated to indoor admission in the departments of Obstetrics, Gynecology, Neonatal, and Service. Residential facilities are available for doctors and nurses, along with a hostel for doctors on duty and medical residents.



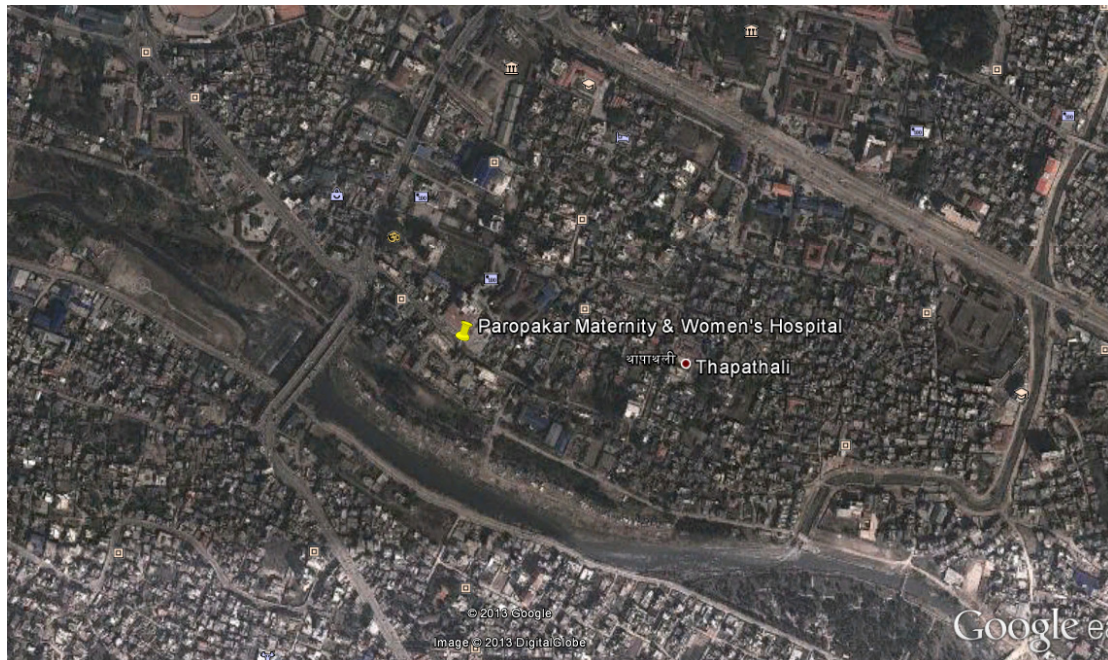


Figure 1: Paropakar Maternity and Women's Hospital in the urban context

### **Assessment Team and Methodology**

GHI's field assessment team consisted of Mr. Hari Kumar, GHI South Asia Regional Director, and Dr. Keya Mitra, Professor of Architecture, Bengal Engineering and Science University Shibpur, India. Dr. Janise Rodgers, GHI Project Manager, and Mr. William T. Holmes, Senior Consultant, Rutherford & Chekene Structural and Geotechnical Engineers of San Francisco, California helped develop the assessment methodology and recommendations.

Prior to conducting the on-site assessment, the GHI team reviewed available DFID-supported Phase I survey reports, papers, and plan drawings generated during the structural and functional assessments, as provided by WHO. Upon arrival in Nepal, the field team attended a meeting comprised of WHO Representative (WR) to Nepal, DFID, structural assessment experts, and functional (i.e., preparedness) assessment experts.

In late May and early June 2013, the GHI field team conducted site visits to assess the seismic vulnerability of equipment, building utility systems, architectural shell elements and contents – often collectively referred to as *non-structural components* – in three major hospitals in the Kathmandu Valley, including the Paropakar Maternity and Women's Hospital.

During the surveys, GHI used the Pan American Health Organisation (PAHO) Hospital Safety Index checklist forms and the United Nations Office for Disaster Risk Reduction (ISDR/WHO (World Health Organization) Safe Hospital Indicators document as data collection tools. The team conducted walk through surveys to assess the potential seismic vulnerabilities of the critical areas of service for normal conditions and emergency management such as the out-patient department (OPD), in-patient department (IPD), operation theatre (OT), and emergency ward. The team also assessed the following on-site utility systems: fire suppression, electrical power, drinking water supply, medical

gas, communication, wastewater and solid waste management; major and specialty medical equipment such as X-ray, Laboratory, specialty diagnostics; and architectural shell elements such as unreinforced brick partition walls and suspended ceilings. The team obtained the information included in this report by conducting in-person evaluations of building contents and utility systems over several days at the hospital; reviewing utility service as-built drawings where available; interviewing or holding discussions with the hospital administration and engineering, maintenance and medical staff; and obtaining supporting technical information from the relevant literature. The field team held discussions with members of the hospital administration including Medical Superintendents, Maintenance Engineers, Nursing Superintendents and hospital staff in the different departments that were surveyed. The team made efforts to visit all important areas of the hospital without disrupting patient care, but some areas were not accessible due to ongoing medical service delivery.

## **Scope**

The scope of this report includes a seismic assessment of the equipment, architectural shell and contents of the hospital's medical buildings, on-site utility infrastructure, and on-site engineering and maintenance offices. The privately operated stores located on the ground floor of the Emergency Building and accessible from the road outside are beyond the scope of this report. Likewise, the canteen is excluded from the scope of this report.

Assessments of structural performance of the buildings during earthquake shaking, the potential ground failure and its impacts, and the hospital's level of emergency preparedness are excluded in the scope of this assessment, because they are being conducted by other teams. Knowing the structural performance and potential for ground failure are crucial in order to determine whether the hospital will likely be able to deliver essential medical care after the shaking stops. The findings in this report must be integrated with the results of assessments of structural performance and potential ground failure in order to draw conclusions regarding whether specific buildings will be usable following a major earthquake.

## **Earthquake Hazard**

Nepal lies in a region of high seismic activity and has a long history of destructive earthquakes. Large earthquakes with magnitude of 5 to 8 on the Richter scale have been experienced throughout the country during the past 200 years, of which 279 earthquakes had epicenters in and around Nepal. In the last century, over 11,000 people lost their lives in major earthquakes in Nepal. Kathmandu Valley is widely known as one of the seismically active areas in the central Himalaya, having experienced large earthquakes in the past centuries. The 1934 Nepal Bihar earthquake severely affected the lives and building stock of Kathmandu Valley. This earthquake was not an isolated event. Three earthquakes of similar size occurred in Kathmandu Valley in the 19th century alone, in 1810, 1833, and 1866. Major damage of probable seismic origin is reported to have occurred in 1255, 1408, 1681, 1803, 1810, 1833, 1866, 1934, 1988 and 1991.

The levels of ground shaking expected, and the effects of site conditions, are discussed in the Location and Site Conditions section.



## Description of the Hospital

Paropakar Maternity and Women's Hospital, Thapathali, Kathmandu, popularly known as PRASUTI GRIHA was established on August 1959. It is situated on the north bank of the Bagmati River, near Thapathali Bridge. It is a tertiary central hospital with 415 beds, out of which 336 are allocated to indoor admission. The Hospital provides services in the areas of Obstetrics, Gynaecology, and Neonatal care. In addition, there are 79 service beds. The site plan in Figure 2 shows the buildings that house the various departments and facilities: (1) Emergency Block, (2) Old Block, (3) New Block, (4) New Ward Block, (5) VIP Block, and (6) Obstetric OPD Block. Figure 3 shows a northeast view of the New Ward Block and VIP Block.

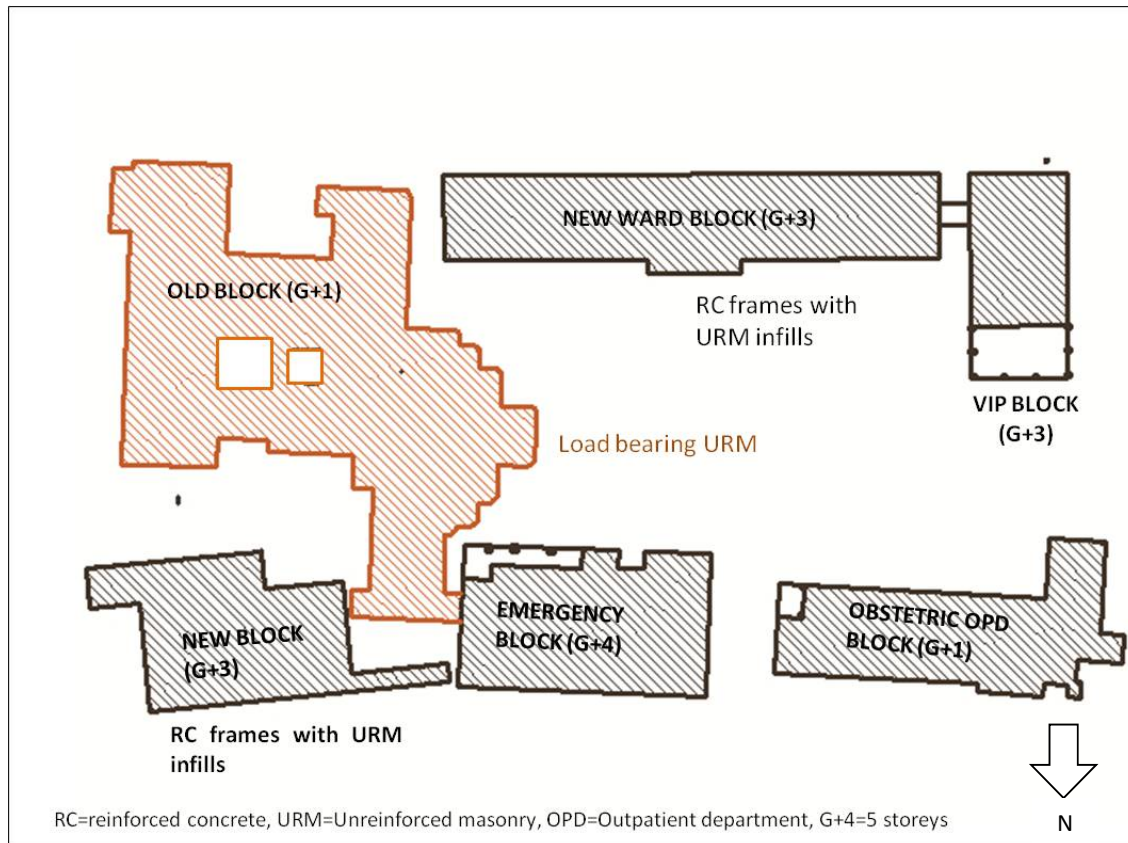


Figure 2: Site Plan (adapted from John Sanday Associates Pvt. Ltd)



Figure 3: The New Ward Block & VIP Block, viewed from the north east side

### **Location and Site Conditions**

Kathmandu Valley evolved during the Pliocene and early Pleistocene. It was submerged and after emergence accumulated fertile soil from late Quaternary sediments. The Kathmandu Valley infilling consists of three-million-year-old fluvial and lacustrine sediments delivered mainly from the mountains in northern parts of the basin. The basement is formed by the Precambrian to Devonian rocks, which are mainly meta-sediments, intensely folded, faulted and fractured. They consist of quartzite, phyllite, schist, slates, limestone and marbles. They are overlain by Quaternary sediments in the valley. The sediment cover has a thickness of 550 to 600m in the central part of the valley.

Paropakar Maternity and Women's Hospital is located in the Thapathali area in the central part of the valley as Figure 4 shows. The hospital is located at an elevation of 1282m, while the Bagmati River with water level of 1280m flows about 100m away from the hospital on the southern side as shown in Figure 5. Soils with high liquefaction potential are often found in recent alluvial deposits near rivers. According to a WHO-Ministry of Health Report from 2002<sup>1</sup>, Kathmandu Valley has a very shallow aquifer usually found at a depth of 1-2m. Based on the high water table and proximity of the river, an assessment of the site's liquefaction potential (which is outside the scope of this report) is essential. Potential effects of liquefaction on the hospital's buildings should be investigated.

<sup>1</sup> WHO (2002). Mitigating Earthquake Risk in Health Facilities. A Structural Vulnerability Assessment of Hospitals in the Kathmandu Valley.



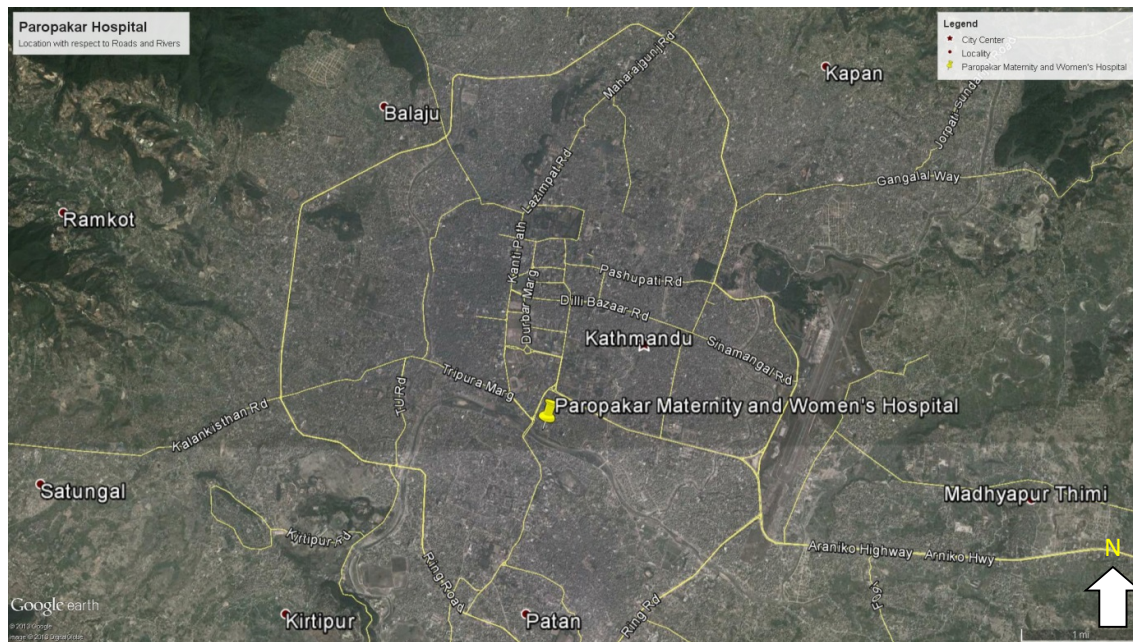


Figure 4: Location of Paropakar Maternity and Women's Hospital in Kathmandu Valley

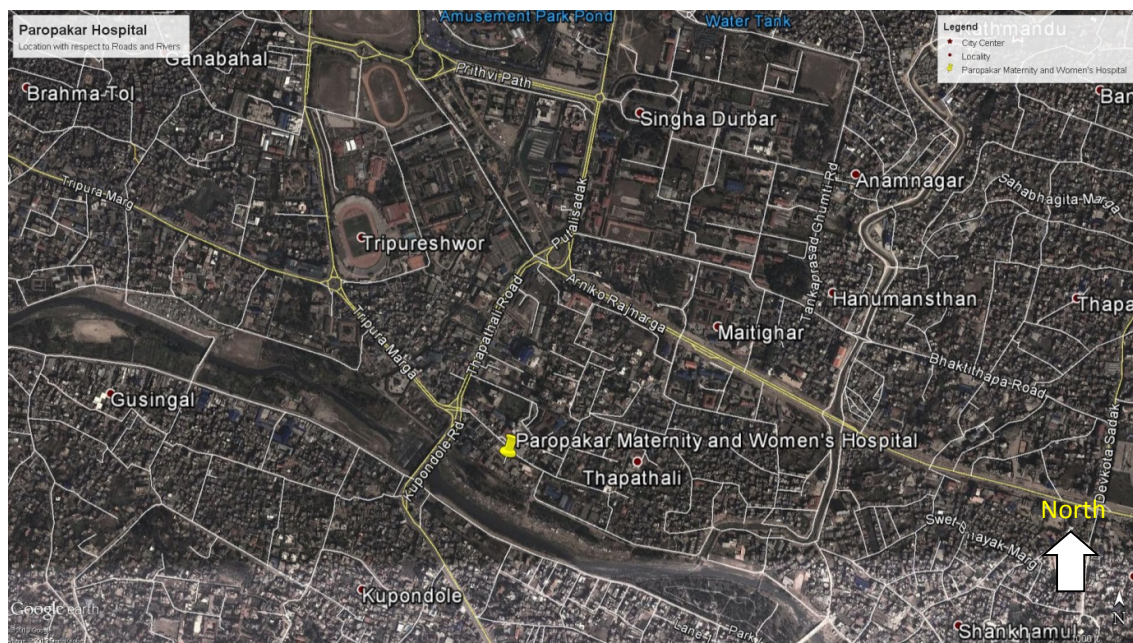


Figure 5: Local transportation routes and proximity to rivers

Assessing the potential for ground failure and site effects is outside the scope of this project, but the level of ground shaking at the Paropakar Maternity and Women's Hospital site is likely to be affected by these factors. A JICA study in 2000-2001<sup>2</sup> found amplification rates ranging from 100% to 200%

<sup>2</sup> Japan International Cooperation Agency (JICA), 2001. The Study on Earthquake Disaster Mitigation in the Kathmandu Valley, Kingdom of Nepal. Volume 1. Summary. Nippon Koie Co., Ltd. And Oyo Corporation.

for an intensity MMI-VIII earthquake, considering peak ground acceleration (pga) values to be between 0.2g to 0.35g. Site specific studies should be carried out during the detailed assessment phase to determine the likely values of ground shaking parameters and the potential for ground failure. The WHO-Ministry of Health Report (WHO, 2002)<sup>1</sup> on structural vulnerability assessment had assumed pga values of 0.2g to 0.35g for MMI-VIII shaking, 0.1g-0.2g for MMI=VII shaking and above 0.35g for MMI=IX shaking. If current site specific studies determine that the anticipated ground shaking will be significantly different than the ground shaking assumed in that report, then the conclusions of this assessment will need to be revisited and potentially adjusted.

## Buildings

The Emergency Block, New Ward Block, New Block, and VIP Block are housed in ground-plus- three-storey buildings built from reinforced concrete frames with brick masonry infill walls and partitions. The Obstetric OPD Block is a two-storey building of reinforced concrete frame with brick masonry infill walls. The two-storey irregular shaped Old Block is a load bearing unreinforced masonry structure built with lime mortar and jack arch roofs. Table 1 summarizes key characteristics of hospital buildings included in this report.

Table 1. Characteristics of Paropakar Maternity and Women's Hospital Buildings with Medical Functions

Block	Year Built	No. Storeys	Type	Major Departments
Emergency Block	1975	G+4	RC w/ brick infill	Emergency Post- Operative Ward Administration Pathology Laboratories
Old Block	1959	G+1	Brick URM w/ lime mortar	Antenatal I and II Labour Central Sterile Supplies Department (CSSD) Radiography Private Ward OT ICU Library Conference Room Office of the Deputy Director
New Block	2010	G+3	RC w/ brick infill	Generator (temporary location) Parking Store OPD Operation Theatres (not commissioned yet)
New Ward Block	1977	G+3	RC w/ brick infill	Observation Ward Blood Bank Pharmacy Special Care Baby Unit (SCBU) Neonatal Intensive Care Unit (NICU) Post-Operative Ward



				Oncology Gynaecology Private Ward and Special Cabins New Paying Ward
VIP Block	1978	G+3	RC w/ brick infill	IVF Center Post Natal Wards I and II Post-Operative Ward Preoperative Ward Private Cabins
Obstetric OPD Block	1966	G+1	RC w/ brick infill	Store, Medical Records, Training Cell Vaccination Units Accounts Section

Most of the hospital's buildings were built between 1959 and 1978, and none of them is likely to have been built to a code with modern earthquake resistant design provisions. Nepal did not begin efforts to develop a national building code until 1992, and the code was not released until 1994. The hospital has a number of reinforced concrete moment-resisting frame buildings with brick infill walls, which were built in the 1960s and 1970s. The GHI team was not able to obtain any information on the designers or agency that constructed the buildings, so it was not possible to determine which code may have been used to design the buildings. However, it is unlikely that the 1960s and 1970s reinforced concrete buildings have reinforcement detailing to provide ductile behavior during earthquakes; such provisions began to appear in building codes in the mid-1970s, and India adopted a code for ductile reinforced concrete seismic detailing in 1993. A structural assessment is required to determine the likely seismic performance of these buildings.

The VIP Block has a partially open ground storey to accommodate a garage in the front of the building (Figure 6). It is unlikely that seismic design considerations for open ground stories were used to design the VIP Block. Therefore, a soft-storey mechanism may occur during an earthquake, which would significantly affect the seismic performance of this building.



Figure 6: Open ground storey in the front portion of the VIP Block

The two-storey Old Block (Figure 7) was built in 1959 with assistance from the Government of India. The building is understood to be constructed of load bearing (unreinforced) brick masonry with lime mortar. In 1959, India had no codes in place with provisions for earthquake resistant design of load bearing masonry buildings. The floors are constructed with jack arches which can be vulnerable to earthquake-induced lateral forces. The tie rods in the jack arch floors appear to be rusted and in poor condition in many locations.



Figure 7: View of the Old Block (left); jack arch roof in Old Block (right);

The Old Block houses the Antenatal Wards, Labour Department, Central Sterile Supplies Department (CSSD) and the Radiography Unit. Loss of functionality of the CSSD due to damages in this building would impair the functioning of the entire hospital. The Radiography Unit also has an important post-earthquake role – supporting care of patients with fractures, one of the most common injuries caused by earthquake damage – and should not remain in this vulnerable block. The first floor houses the Operation Theatre Suite including Major OT, Minor OT, Emergency OT, OT CSSD and Sterilization Unit. The location of such critical facilities in this building is a cause for concern. The seismic behavior of this building, which is being assessed separately by others, will play a major role in the earthquake effects on non-structural elements in these departments.

The Old Block is functionally connected to two buildings: the New Ward Block and the Emergency Block, both of which are reinforced concrete frame structures. The transition areas in both cases are connecting corridors with 20-25mm wide expansion joints. These are likely to be inadequate against pounding effects in an earthquake. The New Ward Block is also divided structurally into 3 separate units with 25mm wide expansion joints and no provision for wider seismic joints to account for pounding effects. The GHI team observed that the oxygen supply lines into the critical care facilities such as the Neonatal ICU (NICU) and Special Baby Care Unit (SCBU) pass through these expansion joints without any flexible connections.

The central staircase in the New Ward Block has floor-to-roof glazing on the external surface. The large (0.86m x 2.133m) unsecured glass panels are attached to 5mm mild steel flat sections which are rusted and poorly maintained. Such large unsecured glass panels are likely to shatter and impede evacuation and egress in the main staircase of the New Ward Block that houses a large number of



patients, staff, and critically ill occupants of the Neonatal Intensive Care Unit and the Special Baby Care Unit. These glass panels should be laminated immediately.

The large reinforced concrete canopy above the main entrance (now closed) to the New Ward Block needs to be assessed for structural safety, as its collapse would block the entrance and impede egress from the building. If the canopy is structurally adequate, it could potentially stop the glass shards from the staircase block from falling onto the road and onto people on the ground.

There have been some additional small rooms built on top of the Old Block (Figure 7 left). The GHI team could not verify if the additional structural demands were accounted for, either in the original design of the Old Block, or when the additions were built.

### **Infrastructure and Utility Services**

The hospital's electric power supply comes from the local grid. Feeder lines from a Nepal Electricity Authority (NEA) substation located 500m from the hospital, supply electricity to two transformers on the hospital premises (Figure 8). Under normal circumstances, the hospital never experiences disruptions in power supply. The hospital has two diesel generators, one manually operated of capacity 50kVA (62.5KW) and a second automatic generator of capacity 150kVA (187.5 KW) to provide backup power, with 100% backup in critical areas of the hospital including Emergency, Intensive Care Units, Operation Theatres, Post-operative Wards, CSSD, X-Ray and water supply, but excluding the New Paying Ward, Gynaecology Private Ward, Antenatal Ward and Annex 12 in the New Ward Block. Lifts are also not covered by generator supply.



Figure 8: The two transformers

The automatic generator has an inbuilt fuel tank and battery support to ensure seamless switchover in case of a power outage. The manual generator has an external fuel tank and battery charger with the power plug located above. Life support equipment such as ventilators all have inbuilt battery capabilities to run for at least 30 minutes without power. Diesel fuel for the generator is stored in the Fuel Tank. Standby fuel is stored in a drum of 200L capacity. The storage drums are located adjacent to the generator. When running to full capacity, the generator consumes approximately 15L of diesel fuel per hour. The generator is placed in a sunken area that has a rough and unfinished

floor. The generator is bolted to this uneven floor without any bracing. The batteries are located on corner supports and not on a continuous platform. They are not bolted to the floor, nor are they braced or restrained to prevent lateral movement. The Low Tension (LT) panels, High Tension (HT) Panel, and other distribution boxes are restrained by steel anchors connected to the brick infill wall.

The hospital does not depend on the Municipal water distribution system. Water is drawn from two bore wells from aquifers 100-200m below ground level through submersible 15Hp pumps (Figure 9). Another two bore wells have recently been commissioned with a manual and motor operated pump each. The raw water is stored in an underground water tank of 20,000L capacity, where chlorination is added. The hospital has a Filtration Unit, which is not in working condition. Chlorine gas is stored in 50L jars, but none were present at the time of the team's visit. From the underground water tank, after chlorination, the water is pumped up for storage in a Tower Tank of capacity 80,000L. This chlorinated water is pumped to the Overhead Water Tanks (Figure 9) located on the roof of the different building blocks, namely, Emergency Block (4 tanks of 2000L each), New Block (3 tanks of 2000L each), New Ward Block (10 tanks of 2000L each), Old Block (4 Galvanised Iron (GI) tanks of 2000L each), and Obstetric OPD Block (6 tanks of 2000L each). The rooftop overhead tanks have a combined capacity of 54,000L. The daily demand for water in the hospital is about 80,000L. There are two pumps of 5Hp capacity each, out of which one is in operation while one is always held in reserve and tested periodically.



Figure 9 : Bore well (left); view of the Tower Tank and rooftop overhead water tank (right)

The hospital has no central boilers for supply of hot water. There is no central HVAC system in place. Window and split type air conditioners with heating and cooling functions are used. Many of these air-conditioning split units are placed outside windows and could be dislodged in earthquake shaking and cause serious injuries to people below. The hospital relies on the city sewer system for wastewater disposal and treatment. Medical waste is incinerated on site.

Medical gas is supplied via oxygen cylinders that are brought in by a supply company truck on a daily basis. The hospital does not have a bulk oxygen tank. Piped oxygen is provided to the OTs and critical areas through a manifold that is fed by 15 cylinders (Figure 10). Piping for nitrous oxide and vacuum (suction) exists but neither is in working condition.



Figure 10: Oxygen Manifold

## **Observed Earthquake Vulnerabilities**

The team assessed the hospital for vulnerabilities in its utility systems, equipment, architectural shell and contents. As noted in the Scope section, an assessment of the seismic structural performance of the buildings was excluded from the scope of this assessment, as others are responsible for structural assessment. Results of the detailed structural assessments were not available at the time of this report, but are of critical importance. The team noted potentially dangerous seismic vulnerabilities in the Old Block, and anticipates that the results of the structural assessments will indicate that this building is likely to experience major structural damage in an earthquake.

## **Vulnerability of Utility Systems and Backup Capabilities**

The Paropakar Maternity and Women's Hospital relies on utility systems such as electrical power, water, and medical gases to function following an earthquake or other emergency. Under normal operating conditions utilities such as electricity are supplied by the local grid. Unlike many modern hospitals that have backup supply capabilities in the event that utility service is interrupted, Paropakar Hospital's backup power supply is vulnerable to earthquake damage. Even for other utilities, such as medical gas, both the supply systems and the distribution systems can be vulnerable to earthquake damage that can interrupt utility services and impede or prevent the hospital from delivering essential medical services following an earthquake. The following sections present utility system vulnerabilities that were observed by the evaluation team.

### **Electrical power system**

The hospital's most important utility system is the electrical power system. Without power, the hospital's essential medical equipment, life support equipment, lighting, and other safety-critical items will not function. The hospital is served by two independent 11KV High Tension feeder lines that supply power to the hospital. According to a study conducted in 2002 (JICA, 2002)<sup>3</sup>, the municipal power supply would become unstable during an earthquake generating Intensity VII

<sup>3</sup> Japan International Cooperation Agency (JICA), 2002. The Study on Earthquake Disaster Mitigation on the Kathmandu Valley, Kingdom of Nepal. Volume 1. Summary. Nippon Koie Co., Ltd. And Oyo Corporation.



shaking. This would cause power disruption. Estimates of the time it would take to restore grid power following earthquakes of different magnitudes were outside the scope of this investigation, but GHI recommends that the hospital obtain these estimates from Nepal Electricity Authority for planning purposes.

The hospital has two transformers of 250 kVA capacity each. These transformers that receive the HT power supply are placed on a pair of poles adjoining the boundary wall (Figure 8). These are prone to toppling in earthquake shaking and need to be braced. Even if grid power returns, the hospital may not be able to access it due to damage to the transformers. During the critical response period immediately following the earthquake, the hospital may be dependent on backup power.

The evaluation team observed multiple vulnerabilities in the backup electrical power system, which is likely to cause failure of the backup system in a strong earthquake and possibly in a moderate earthquake, leaving the hospital completely without power. Both generators are placed on sunken floors with uneven and unfinished surfaces. They have a few bolts fixing them to the floor. However, the number and spacing of the bolts and their inadequate connections to the uneven floor add to the possibility of their being dislodged in moderate earthquake shaking (Figure 11).

There is no exhaust system in place, nor are there any muffling elements. There has been an attempt to anchor some of the ancillary systems such as the fuel tank and electrical cabinets (Figure 12) through fabricated steel anchors. However, safety practices seemed to be lacking: the battery charger and the power connection to it are placed on top of the fuel tank, which could lead to a fire in case of any short circuit in these wires (Figure 13). The tank also lacks flexible piping, and supply of generator fuel would be affected if the rigid pipes break during earthquake shaking. The manual generator has batteries abutting the generator. The batteries are located on corner supports and not on a continuous platform. They are not bolted to the floor, nor are they braced or restrained to prevent lateral movement.



Figure 11: Manual generator (left); automatic start generator (right)



Figure 12: Fabricated anchorage for electric switchbox



Figure 13: Battery Charger and power plug placed over the diesel tank

The new automatic generator has an inbuilt fuel capacity of 25L while the old manually operated generator has an external fuel tank of 100L. An additional 200L of diesel fuel is stored within the generator room in a drum for use in emergencies. Under normal conditions, the generators would have enough fuel to power the hospital for about 20 hours. PAHO recommends that hospitals store enough fuel for at least five days. The generators are tested periodically due to loss of grid power supply for short periods of time. However, they have not been tested for extended running and could develop heating problems if run continuously for over six hours, because they are cooled with water, which must be added manually. The hospital does not have any permanent fuel tank reserve.

The generators are housed in the ground floor of the new block, a reinforced concrete building. However, the two wythe brick masonry infill walls do not go up to the underside of the beam and may not be stable in out-of-plane earthquake shaking. The hospital has no history of being affected by flooding from the nearby river. However, in a rare flooding, the generator area being at the ground level could be flooded and cause a complete loss of power to the hospital.

The hospital has procured one additional generator, but it has not yet to be commissioned and is presently stored in the parking lot (Figure 14).



Figure 14: Third generator not yet functioning, stored unused in parking lot

### **Water Supply System**

The hospital does not use water from the municipal supply. Water is drawn from the aquifer level (100-200m deep) through a two bore wells using two 15Hp pumps which are used alternately. The water supply system is fully supported by the power backup system and will therefore function during any interruption in the power supply. However, the earthquake could damage the treatment system, halting the ongoing supply of treated water. Adequate water storage facilities are critical to ensuring continued functionality of a hospital after a seismic event. PAHO recommends that hospitals have domestic water storage capacity of at least 300L per day per bed for at least three days. For 495 beds, the hospital should have 148,500L per day storage capacity for domestic water. At present the hospital has storage capacity for 154,000L of water, which is just over a day's supply as per PAHO standards; PAHO's 3-day supply recommendation would require storage for 445,500L. The storage capacity of 154,000L takes into account the team's finding that two 2000L capacity roof top water tanks had collapsed due to extended exposure to sunlight and have not been replaced.

Water storage tanks for untreated water are located in secure locations but there are no measures for their protection against damage from shaking. Evaluation of the seismic resistance of the ground level reinforced concrete water tank (Figure 15) was outside the scope of this assessment, but it is possible that the tank, the unreinforced masonry pump house, or the pipes connecting the tank to the hospital could be damaged and cause leakages. None of the inlet and outlet pipes have flexible connections, and the rigid connections could be damaged in earthquake shaking.





Figure 15: Underground water storage tank (left); Rigid pipes connecting roof top water tanks (right)

Roof water tanks on various building roof tops are all placed on small platforms in a line raised on the roof surface. There is an inlet of water supply coming in from the Tower Tank to one of the tanks and the three or four tanks (as the case may be) are connected with rigid pipes at the bottom (Figure 15). In any earthquake shaking, the tanks are likely to be displaced and the rigid connections will break, resulting in leakage of water from all the tanks. Since water flows from the Tower Tank by gravity, this could result in loss of much water from the main tank before leakage is detected.

### **Fire Suppression System**

There is no separate water tank for fire-fighting, nor does the hospital have an operational fire-fighting system in place. The fire suppression system installed at the time of construction of the OPD and Emergency Block is out of commission. There is no external fire hydrant in or near the hospital premises. The field team observed a number of fire extinguishers, which will presumably be used by the security personnel in case of a fire. None of the staff members the team interviewed had received training for using fire extinguishers. The lack of a proper fire suppression and fire-fighting system and training on fire safety is a major deficiency in the hospital.

### **Medical Gases**

There is no centralized piped gas system serving the entire hospital. The oxygen bank supplies piped oxygen only to the operation theatres and post-operative wards. Other gases, such as nitrous oxide for the operation theatres, and oxygen for other locations, are supplied by individual cylinders. The central suction system and the nitrous oxide supply piping are not operational.

The oxygen bank uses a manifold with 15 unanchored cylinders that are connected to it by semi-flexible copper tubing (Figure 16 ). During an earthquake, a number of cylinders will topple, disconnect from the manifolds, and possibly leak, leading to a possible fire and explosion hazard. The hospital stores 50 to 60 cylinders of oxygen cylinders of 680L and 8 cylinders of 130L. While the piping is secure, there is no flexibility where the lines cross expansion joints and into a different building (Figure 16). This may cause damage during shaking. The medical gas storage facility is accessible, and the cylinders and related equipment are fairly well protected in exclusive storage areas operated by trained personnel. However, the storage area is an unreinforced masonry building

that may suffer earthquake damage that would disrupt the oxygen supply system. Oxygen and other medical gas cylinders are not restrained in any of the storage locations in the hospital.



Figure 16: Oxygen cylinders and semi flexible copper tubing (left); rigid oxygen lines cross expansion joints in the New Ward Block (right)

The hospital may not have a problem with regard to medical gas supplies since the supply outlet is located within Kathmandu. (Assessment of the medical gas supplier's facility was outside the scope of this assessment.) However, the hospital's emergency plan should account for the possibility that the supplier's facilities may be damaged, that their electric supply may be disrupted, and that roads between the hospital and the supplier may be blocked with debris from collapsed buildings.

### **Communication Systems**

The hospital currently uses landline and mobile phones as the major communication systems. There are three lines to the telephone exchange and three other direct lines, one each for the Operation Theatres, the Special Care Baby Unit, and the Director's office. Internet and telephone cables are not properly laid out, which may impede repairs if there is damage to these lines, particularly where they cross locations where differential movement is expected, such as seismic joints. However, neither landline nor mobile phone systems are likely to be functional in the aftermath of a significant earthquake affecting Kathmandu Valley. As numerous past earthquakes have shown, phone systems often become overloaded with calls and go down even if damage is limited. In more damaging earthquakes, phone system equipment, such as mobile phone transmission towers and landline central switching stations, can be damaged. While the length of the outage depends on vulnerabilities in Kathmandu's landline and mobile phone systems (which are outside the scope of this assessment), the hospital should assume neither will be available for several days or more following a major earthquake.

There is no radio or satellite communication system available, leaving the hospital with no backup communications system. There is a public address system that uses loudspeakers operated from the reception, which was found to be in satisfactory condition, but not properly anchored to the walls, and did not have battery backup.

### **Heating, Ventilation and Air Conditioning Systems**

While the hospital does not have a central HVAC system or boilers, the buildings do have numerous small air conditioning units. A number of these units sit unanchored on narrow exterior façade ledges or steel cages, where they can fall during shaking and kill or injure those below (Figure 17).



Figure 17: Air conditioning split unit placed dangerously on building exterior

### **Lifts and Vertical Transportation**

The hospital has two lifts, located in the New Ward Block and the New Block, neither of which is operational during generator power supply. The evaluation team assumes that the lift in the New Ward Block was not designed for earthquake forces, because there are no seismic provisions for lifts in the Indian Standard codes, and the buildings were constructed prior to development of the Nepal National Building Code. The lift rails and counterweights are vulnerable to earthquake damage. During strong shaking, the counterweights can derail and crash through the top of the lift car. It should be noted that lift machinery is located at the top of buildings, where shaking tends to be strongest, because the building amplifies earthquake motions (Figure 18).

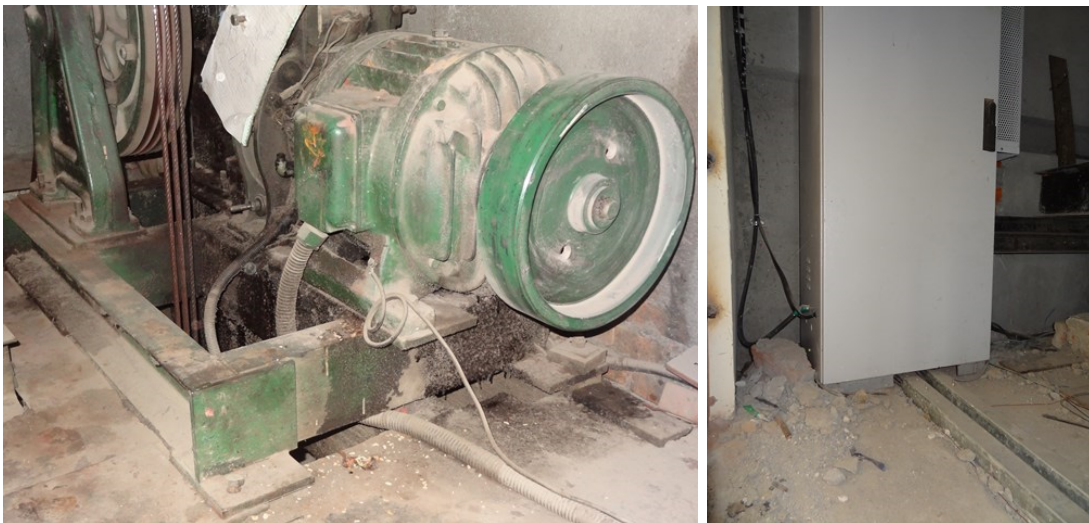


Figure 18: Machine room of old lift (left); Unanchored electric box of new lift (right)

In the recently constructed New Block, the lift machinery seems to be anchored to the walls. The rails and counterweights need to be checked for adequacy under the design seismic forces. The electrical panel in the lift room did not seem anchored (Figure 18) and could be damaged in earthquake shaking, resulting in loss of lift service. The hospital has no ramps for floor-to-floor access. The field team did not obtain direct access to the lift machinery and controls, but could observe it through a locked grill door.

## **Medical Equipment and Contents**

The field team conducted a visual survey of the medical equipment and contents in areas of the hospital important for providing post-earthquake diagnostic and treatment care, listed in Table 2.

Table 2: Areas Assessed for Seismic Vulnerabilities of Medical Equipment and Contents

	Block	Department
1.	Emergency Block	Emergency Observation and Ward Post-Operative ward Administrative Offices Histopathology Lab, Grossing Room, Pathology Lab, Parasitology Lab, Haematology Lab
2.	New Block	Generator, parking and store OPD Operation Theatres (not yet functional)
3.	VIP Block	Pre-Operative Ward Post-Operative wards IVF Unit
4.	New Ward Block	Private Wards Post-Operative Wards Neonatal Intensive Care Unit (NICU) Special Care Baby Unit (SCBU) Pharmacy Blood Bank
5.	Old Block	Antenatal Wards Labour Rooms CSSD Radiography Private Wards Operation Theatre and ICU Major, Minor and Emergency OTs OT CSSD Library Conference Room Office of the Deputy Director
6.	Obstetric OPD Block	Stores Accounts Section Medical Records and Statistics Vaccination Rooms Training Cell and Classrooms



Most of the medical equipment and storage systems have not been secured or anchored for protection against earthquake shaking. In the Operation Theatres and Post-Operative Wards, lamps, anaesthesia equipment and surgical tables are in fair condition and operational. The OT lights are firmly secured to the roof slabs, but being on long extended arms, the appropriateness and depth of the anchor bolts need to be ascertained to ensure stability of this critical equipment. As the hospital is the most important women and children's hospital, a high volume of testing is done in the various laboratories in the hospital. The laboratories are well equipped, but none of the instruments is anchored, and labs could suffer loss of functionality due to the sliding / toppling damage to testing equipment. X-ray and imaging equipment is fixed to the roof, and rails are embedded in the floor. However, the control equipment is freestanding and could topple and be damaged by shaking.

Medical trolleys on wheels, without locking mechanisms, are in almost all parts of the hospital and could be displaced in earthquake shaking and could lead to spillage of medicines, injuries and blockage of exits. The refrigerators storing medicines in the wards, nurses' stations and the blood bank refrigerators are not anchored and could fall down, causing loss of critical medical supplies. Bedside monitors, where present, were all anchored to the walls and did not seem to be in danger of losses or of falling on patients. In many wards, oxygen cylinders are kept in a haphazard manner near bedsides and near exits. These could topple in any earthquake shaking and could cause leakages, injuries or blockage of exits.

The Central Sterile Supplies Department (CSSD) is a critical facility for any hospital, as all sterilisation occurs there. None of the autoclaves (Figure 19) have been anchored to withstand earthquake shaking and could topple, putting the CSSD out of service which could lead to non-functionality of the Operation Theatres. Autoclaves also have small distilled water tanks (Figure 19) attached to them, which are placed on unstable stands vulnerable to toppling even at low levels of shaking. The water pipes connected to the autoclaves all have rigid connections, which could lead to breakages and leakages and will likely affect the functioning of the CSSD in any earthquake.



Figure 19: Autoclaves (left); unanchored water tank for autoclaves (right)

In all the treatment and diagnostic facilities surveyed, the work tables, computer tables, laboratory shelving, and storage units are not adequately secured or fastened for protection against lateral shaking (Figure 20). Moreover, in numerous locations, tall shelves full of glass contents are placed next to exit doors. They will likely topple in an earthquake, spilling their contents, and broken glass and liquid on important evacuation routes (Figure 20).



Figure 20: Officer sitting among dangerous falling hazards (left); unanchored cupboards and shelves with more loose objects placed above (right)

In many spaces, especially in nurses' rooms and certain wards, tall cupboards are used as partitions and could pose a threat, in terms of injuries and loss of exits, to room occupants. Many corridors are lined with cupboards and lockers that not only reduce the width of exit pathways, but will also fall down during earthquake shaking and block the exit path (Figure 20). Many wards have glass partitions that are likely to shatter during shaking, causing injuries and impeding egress (Figure 22).



Figure 21: Blocked exit of Nurses' Room (left) and corridors with reduced effective width due to furniture placement (right)





Figure 22: Glass partition walls in wards

### **Architectural Shell and Egress**

The oldest building in the hospital, the Old Block, is an unreinforced masonry building with jack arch roofs built in 1959. Such buildings are prone to significant damage, and in some cases may collapse under strong earthquake shaking. These buildings were not constructed under the current Nepal Building Code, yet most of the critical equipment and services of the Paropakar Hospital are housed in the Old Block, which will affect the functionality of the hospital in a post-earthquake scenario.

Suspended ceiling in some of the functional areas in the Old Block are made of acoustical tiles placed on a timber framework, which in turn is hooked to a corrugated galvanized iron (CGI) roof (Figure 23). The CGI sloped roof does not have positive connections with the walls and would act like a flexible diaphragm in earthquake shaking. As a consequence, both the roof and the suspended ceiling would likely suffer damage.



Figure 23: Suspended ceiling over parts of the Old Block.

In the New Ward Block, the reinforced concrete (RC) sloped roof above the staircase and the sloping sunshades have brick roof tiles fixed to RC slabs with cement mortar. The system relies on the inbuilt interlocking design of the tiles to prevent their collapse in earthquake shaking. There are no metal ties for additional anchorage. If not anchored/fixed properly, tiles tend to slide off during shaking and can fall on people down below, especially when the tiles are above an entrance.

As mentioned above, many of the corridors have been partially blocked by cupboards, racks, and lockers. However, the most critical aspect is that the main exits of the New Ward Block and the Old Block (Figure 24) are locked, and the space in front is used for the parking of staff two-wheelers. This means that a person at the New Ward Block would have to walk through the Old Block and exit the building through a corridor in the Emergency Block. This presents a very dangerous and potentially life threatening scenario, as every occupant from every floor in the New Ward Block, the Old Block and the Emergency Block would have to use a single exit. For occupants of the New Ward Block, the travel would also be through a circuitous route that would be difficult to negotiate in an emergency.



Figure 24 Main exit of Old Block locked (left); and main exit of New Block blocked

The hospital's buildings have numerous brick partitions that can crack and fall during strong earthquake shaking. Masonry falling from partitions is a threat to those nearby, and affects the ability of medical staff to work in disrupted areas.

## **Recommendations and Conclusions**

The hospital facility has numerous seismic vulnerabilities in its utility systems, equipment, architectural shell and contents, which should be addressed as part of a larger effort to improve the seismic performance and functionality of the facility. Many of the hospital's most critical medical services are delivered in the Old Block building, which was built in the late 50's of unreinforced masonry and does not contain any earthquake-resistant features. Most of the hospital's other buildings we built in the 1970s and likely do not have the earthquake resistant features required by modern building codes. If severe structural damage were to occur, it would present the greatest threat to the safety of the hospital staff and patients. For this reason, conducting a detailed

assessment of the earthquake vulnerabilities of the hospital's buildings, as is occurring during the second and later phases of the current project, must take the highest priority. In addition, such old buildings may not be functionally suited to delivering modern medical care. It is recommended that the critical services of the hospital such as the Operation Theatres, CSSD, etc. be moved to other more recent buildings which are built to earthquake resistant standards.

Experiences in major, ongoing hospital seismic safety improvement programs in Turkey and California demonstrate that there are a number of serious and significant issues involved when seismically retrofitting hospitals. These include disruption to existing operations if hospital buildings cannot be vacated; increased construction time and costs to manage the disruption; costs to construct the extensive structural retrofit measures often needed in older buildings to provide the high level of seismic performance desired for hospitals; costs to anchor and brace utilities and the architectural shell to prevent damage that would induce shutdown of critical services areas; cost to repair building elements in poor or deteriorated condition; and the fact that for all the effort, medical staff are still using a building that may not suit their care delivery needs. As a result, a number of hospital buildings in Turkey and California have been replaced with new buildings designed for high seismic performance and modern medical care delivery, rather than being retrofitted. Replacement may well be a preferable option for some Nepal hospital buildings as well.

The recommendations in this section must be integrated into decisions to replace or seismically retrofit seismically vulnerable buildings. While GHI recommends that the highest priority recommendations be implemented as soon as possible, without waiting for retrofit or replacement to take place, the remaining recommendations will be most cost effective if performed in conjunction with a seismic retrofit or other construction. If the building were replaced quickly, the remaining recommendations for that building would not need implementing.

The following sections list specific recommendations to address seismic vulnerabilities identified in prior sections, organized by the major utility system and/or element type. Table 3 organizes mitigation measures by level of priority.

### **Backup Electrical Power**

Both the generators and the electrical backup supply system need to be seismically protected so that they will not come off their supports, and so that the power supply remains uninterrupted. The additional generator available in the campus should also be commissioned to provide robustness to the backup supply and must have facilities to enable automatic switchover to backup facilities when the main grid fails.

The hospital should continue the practice of providing all critical medical equipment with emergency backup power independent of the hospital's backup generators. The hospital should store enough additional fuel to power the generators for the PAHO-recommended five days or the estimated length of time to restore grid power, whichever is longer. The onsite electrical power backup system is highly susceptible to failure even in moderate earthquake shaking. The power backup system needs significant strengthening so that it can support the hospital's emergency power needs until power supply from the main grid is restored.

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## **Communications**

The hospital should obtain backup communications capability, internally and externally, to enable coordination with other hospitals, government agencies and responders after a major earthquake.

## **Water Systems**

Overhead (rooftop) tanks need anchoring to prevent sliding or toppling in moderate to severe earthquake shaking. Water treatment equipment needs to be anchored to prevent damage that would disable the treatment system. Replace rigid connections to the Tower Tank and overhead water tanks and to filtering/ water treatment equipment with flexible connections, to accommodate differential movement and prevent breaks that could drain the tanks. Water supply lines crossing building joints should have flexible connections at the joints sufficient to accommodate the expected amount of differential displacement. The fire suppression system needs to be repaired.

## **Medical Gas**

Cylinders in the oxygen bank, in the various wards, and in other locations need restraints to prevent them from toppling during earthquake shaking. At present the hospital does not have adequate backup supply of oxygen cylinders to last more than a day of normal use. There should be provisions for storage of at least five days' supply within the premises. Medical gas lines crossing building joints should have flexible connections to accommodate differential movements.

## **Lifts and Vertical Transportation**

The earthquake safety of the lifts (especially the lift in the New Ward Block should be ascertained by a qualified structural engineer, and corrective actions should be taken if found necessary. The electric panel in the new lift should also be restrained to prevent damage in any earthquake shaking.

## **Medical Equipment, Contents and Furnishings**

The hospital needs to make an inventory of the most critical medical equipment and determine whether or not it is adequately anchored/protected against seismic forces. For any new equipment, seismic anchorage should be included as part of the purchase contract. The pharmacy should have anchored racks and shelf restraints. Determine the adequacy of the Operation Theatre light fixtures to resist earthquake shaking, and corrective actions should be taken if found necessary.

## **Architectural Shell and Egress**

The structural assessment report of the Old Block building may suggest remedial measures for reducing risk due to falling masonry. In the reinforced concrete buildings, single wythe brick partitions that are located in areas where critical care is delivered, or where patients and staff could be struck by falling masonry, should be braced with strongbacks to prevent partition collapse. Exterior glass elements and roofing tiles pasted on the roof of the sloped portions of the new ward block located above hospital entrances and locations where people congregate need to be evaluated to verify that they will remain in place during the expected earthquake shaking. Exit doors should be unlocked, and doors and corridors should be kept clear of furnishings and contents.

## Recommended Priorities for Implementing Mitigation Measures

The table below shows recommended priorities to help guide implementation efforts.

Table 3. Recommended Priority Levels for Specific Mitigation Measures

Priority Level	Specific Mitigation Measures
<b>Highest</b> (Critical safety)	<ul style="list-style-type: none"> <li>Relocate critical services from the Old Block building if detailed structural assessment demonstrates other buildings on site will provide better performance</li> <li>Seismically protect emergency generator</li> <li>Anchor generator base</li> <li>Brace muffler / exhaust system</li> <li>Restrain batteries and other equipment in the generator room</li> <li>Restrain transformers</li> <li>Restrain medical gas cylinders against toppling</li> <li>Provide backup communications capacity</li> <li>Repair the fire suppression system</li> <li>Unlock main exits in New Ward Block and Old Block</li> <li>Relocate furnishings and contents blocking portions of doorways and corridors necessary for emergency egress</li> <li>Unlock exit doors to the staircase in the Post-Operative Ward in the first floor of the Emergency Block</li> <li>Large glass panels in wards etc. should be laminated</li> </ul>
<b>High</b> (Critical care delivery)	<ul style="list-style-type: none"> <li>Seismically protect and bring online the non-operational generator</li> <li>Store additional fuel for emergency generator and connect with flexible connections</li> <li>Remove wires etc. from over fuel tanks that pose a fire risk</li> <li>Seismically protect water system components</li> <li>Install flexible connectors and shutoff valves on tanks to prevent pipe break from draining system</li> <li>Anchor tanks, especially rooftop tanks</li> <li>Anchor critical equipment such as pumps</li> <li>Assess the potential for shaking or liquefaction damage to the boreholes, submersible pump and pipe connections</li> <li>Secure major medical equipment in critical care areas</li> <li>Restrain brick partitions with strongbacks in critical care areas, or replace with lightweight partitions</li> <li>Install shelf restraints in pharmacy, key storage serving critical care areas, and medical records to reduce cleanup required post-earthquake</li> <li>Brace or remove exterior falling hazards including glass above exit doors</li> <li>Brace racks and install shelf restraints in the CSSD to keep important sterile supplies on the shelves</li> <li>Anchor sterilizers / autoclaves</li> <li>Ensure maintenance/ refilling of fire extinguishers. Train staff members in the use of emergency firefighting equipment.</li> </ul>

<b>Medium</b>	<ul style="list-style-type: none"><li>• Increase water storage capacity. Replace broken water tanks on the roof. Protect water tanks from sunlight damage. Ensure better quality of tanks in future purchases.</li><li>• Secure high-value or difficult-to-replace medical equipment in Laboratories and other areas</li><li>• Restrain brick partitions near patient beds in wards, or replace with lightweight partitions</li><li>• Relocate or anchor large and heavy furnishings in work or patient areas</li><li>• Install flexible connectors on water and medical gas pipes</li></ul>
<b>Lower</b>	<ul style="list-style-type: none"><li>• Restrain remaining brick partitions</li><li>• Secure remaining medical equipment</li></ul>

## **Conclusions**

The mitigation and preparedness measures necessary to help keep the hospital functional will take time to implement, and will need to be integrated with the overall seismic safety improvement plan, then planned and spread out over a number of years. The hospital will then be much better prepared to serve the community in the event of an earthquake. Because Paropakar Hospital is one of the largest and most important women's hospitals in the Kathmandu Valley, these measures are of critical importance to help keep the hospital functioning after a damaging earthquake.