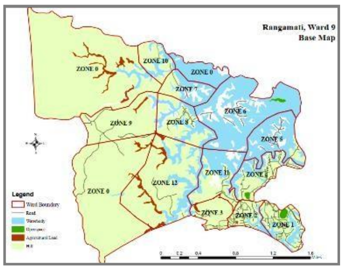
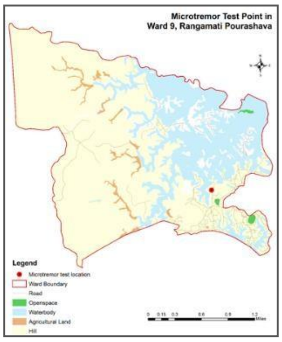
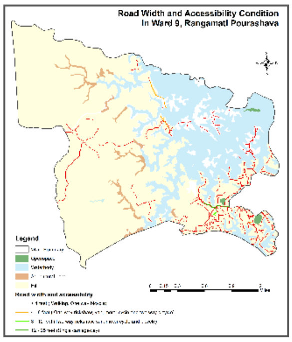
Draft Earthquake Contingency Plan

Ward 9,Rangamati Municipality







Department of Disaster Management

Ministry of Disaster Management and Relief

March, 2021

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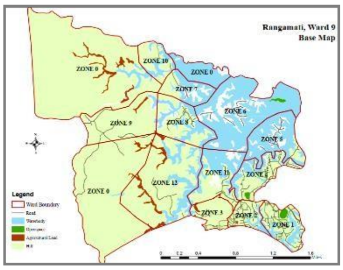

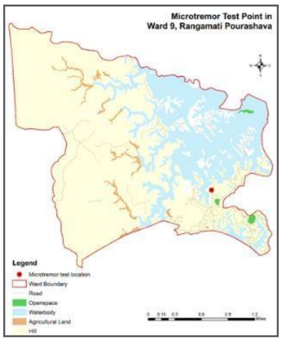

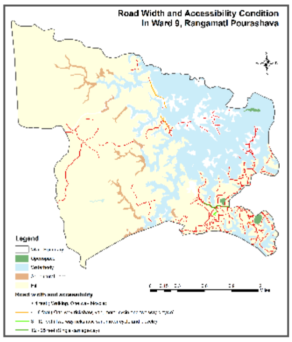

BUET-Japan Institute of Disaster Prevention and Urban Safety (BUET-JIDPUS)
Department of Urban and Regional Planning
Department of Civil Engineering
Bangladesh University of Engineering and Technology (BUET),
Dhaka-1000, Bangladesh.

March, 2021

Project Team Members

Faculty:

- Prof. Dr. A. F. M. Saiful Amin, Director, BUET-JIDPUS, Professor, Dept. of Civil Engineering, BUET
- Prof. Dr. Raquib Ahsan, Professor, Dept. of Civil Engineering, BUET
- Prof. Dr. Ishrat Islam, Professor, Dept. of Urban and Regional Planning, BUET
- Prof. Dr. Mohammad Shakil Akther, Professor, Dept. of Urban and Regional Planning, BUET
- Ms. Uttama Barua, Assistant Professor, Dept. of Urban and Regional Planning, BUET
- Ms. Tasnim Tarannum, Lecturer, BUET-JIDPUS
- Ms. Shamontee Aziz, Lecturer, BUET-JIDPUS
- Ms. Sadia Afroj, Lecturer, Dept. of Urban and Regional Planning, BUET

Research Assistant:

- Mamata Jafrin Mouli, Dept. of Urban and Regional Planning, BUET
- Shegufta Zahan, Dept. of Civil Engineering, BUET

Officer and Technical Personnel:

- Md. Samsur Rahman, BUET-JIDPUS
- Md. Jasim, BUET-JIDPUS
- Azader Rahman, BUET-JIDPUS
- Md. Haroonor Rashid, BUET-JIDPUS

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CHAPTER 1: INTRODUCTION

Earthquakes can occur without any warning resulting in widespread damage; high numbers of fatalities and injuries; destroying buildings and other physical infrastructure and facilities. It may have adverse effect on economic, social and political sector which can drive the entire nation to disastrous consequences (CDMP, 2014). To mitigate the earthquake risk, proper planning and management are required through investigating the interrelated issues based on earthquake vulnerability assessment.

1.1 Background of the Project

Bangladesh is geographically vulnerable to earthquake due to the existence of several fault lines and tectonic plate boundaries. Historical evidences of earthquake including their severity near and within the country compound the future threat. Moreover, rapid urbanization, population growth, migration, and development of economic activities are also inducing impetuous increase of vulnerability (CDMP, 2014). A severe earthquake in this country will cause a large number of human casualties, huge damages of infrastructures, social and economic loss etc. and a big earthquake is anticipated in near future (Alam *et.al*, 2008; CDMP, 2009; Ministry of Disaster Management and Relief, 2015). To ensure a useful response to a severe earthquake in an area; an organized earthquake risk management planning is essential at local level, including contingency plan based on seismic exposure assessment and building and socio-economic vulnerability assessment. Socio-economic vulnerability assessment reveals the community's characteristics leading to their earthquake vulnerability and the potential impact of earthquake on their social and economic life (Lal *et.al*, 2011). Contingency planning is a course of actions, which aim to prepare an entity to respond well to an emergency and its potential humanitarian impact (CDMP, 2014). In other word, contingency planning is making advance decision about human resource and financial resource management as well as ensuring communication and coordination with a range of technical and logistical responses considering possible disaster or emergency (GHI, 2014).

A brief idea about contingency plan for earthquake is also found from National Plan for Disaster Management (2010-2015). According to "National Plan for Disaster Management (2010-2015)" of Bangladesh, the pre-disaster, response and post-disaster activities are categorized into nine functional clusters to prepare plan for earthquake. They are overall command and co-ordination, search, rescue and evacuation, health, relief services and shelter, water supply, sanitation and hygiene, restoration of urban services, transport and security and welfare (GoB, 2010).

Bangladesh hopes to transform from Least Developed Country (LDC) category to developing Country by 2024 through better health and education, lower vulnerability and an economic boom (UN, 2018). Disaster risk reduction remains a key priority of the Government of Bangladesh, which is reflected in its Five-Year Plans, Perspective Plan, Bangladesh Delta Plan, and various national policies. Bangladesh has also adopted global frameworks like SDGs, Sendai Framework etc. However, Bangladesh has to maintain a holistic approach and to mainstream disaster risk reduction into development planning based on achievements and lessons. Bangladesh government and United Nations Development Programme (UNDP), UN Women and United Nations Office for Project Services (UNOPS) have jointly initiated the National Resilience Programme (NRP) with the financial support of the Department for International Development (DFID) and the Swedish International Development Cooperation Agency (SIDA) to sustain the resilience of human and economic development in Bangladesh through an inclusive and gender responsive disaster management. The programme aims at to provide strategic support to improve national capacity to keep pace with the changing nature of disasters.

The programme consists of four sub-projects or parts. Each sub-project is implemented by one implementing partner from the Government. These implementing partners are: Department of Disaster Management (DDM) of the Ministry of Disaster Management and Relief, Department of Women Affairs of the Ministry of Women and Children Affairs, Programming Division of the Ministry of Planning, and Local Government Engineering Department of the Ministry of Local Government, Rural Development and Co-operatives.

In NRP, DDM part aims to work towards improving community resilience by creating replicable, cost-effective models around DRR inclusive social safety nets, pro-active response solutions, earthquake preparedness, search and rescue, community-based flood preparedness that have shown promise in earlier initiatives. The objectives of the Department of Disaster Management part are:

- To advocate for implementation of the Sendai framework and build necessary capacity to monitor the implementation.
- To strengthen disability-inclusive, gender-responsive national capacities to address recurrent and mega disasters (including training of key personnel).
- To strengthen disability-inclusive, gender-responsive community preparedness, response and recovery capacities for recurrent and mega disasters.

As earthquake is a sudden perilous natural disaster and it can cause large-scale damage, an inclusive earthquake risk management approach is required to minimize the loss. To ascertain an effective response to severe earthquake event; an organized earthquake risk management planning is necessary at local level, including contingency plan based on soil characteristics, structural analysis of building and socio-economical context. Realizing this National Resilience Programme (NRP) under the Ministry of Disaster Management and Relief of the People's Republic of Bangladesh has taken initiative to develop a minimum preparedness package for earthquake preparedness for the cities. Activities are implemented in Rangpur, Tangail, Rangamati and Sunamganj. This report covers preliminary contingency plan of Ward 8 of Rangamati Pourashava.

1.1.1 Experience from Mymensingh Municipality

BUET and UNDP conducted similar project in Ward 14 of Mymensingh Municipality in the year 2016-2017. This research work was undertaken to develop community-based earthquake risk reduction and management plan in Ward No. 14 of Mymensingh Pourashava. For the purpose, the research team prepared a contingency plan for the study area in consultation with the local community. The tasks included assessment of seismic risk, assessment of the building and socio-economic vulnerability, and finally preparation of earthquake contingency plan for the area. The project was launched through a workshop at Mymensingh Pourashava on 6th April 2017. This consultation workshop helped the researcher to understand the issues and to determine the scope of the work.

The earthquake contingency plan prepared to reduce seismic vulnerability of the study area includes temporary shelter planning, emergency health facility planning, Ward Co-ordination Center planning, evacuation route planning, and household level preparedness planning. For temporary shelter demand, two scenarios were considered. In Scenario-1, it was assumed that 50% residents of buildings which will collapse or damaged during an earthquake would need shelter. It was estimated that around 2,273 people would need shelter in this scenario. On the other hand, in Scenario-2, it was assumed that all the residents of the contingency plan area would require temporary shelter. Considering the preference and acceptability of local people, structural safety and accessibility of the proposed shelter, 28 places were identified for temporary shelter in dry season including open spaces, educational institutions and religious places and 24 places in wet season including open spaces, educational institutions and religious places. These places could accommodate 11,277 people in dry season and 5,209 people in wet season.

Considering preference and acceptability of local people, structural safety, and accessibility, 26 health facilities including hospitals, clinics, and diagnostic centers in the study area were proposed to serve the injured people after an earthquake. Comparing the availability and probable requirement it can be concluded that the facilities within the study area are enough to treat the estimated injured persons after an earthquake. In addition, roads that could be blocked were identified. It was found that the roads in the proposed evacuation route have road width less than or equal 6ft. These roads will be only accessible by walking, cycle or motorcycle, one-way rickshaw or van. Thus road widening initiative by the Pourashava is necessary. To access narrow roads, customized non-motorized vans can be used during a rescue operation in disaster.

To ensure proper management of these temporary shelters and emergency health facilities, Temporary Shelters Management Committee (TSMC) and Emergency Health Facility Management Committee (EHFMC) were proposed with their composition, role, and responsibility in different phases of disaster management.

These proposed committees need to coordinate their activities in consultation with the Ward Disaster Management Committee (WDMC).

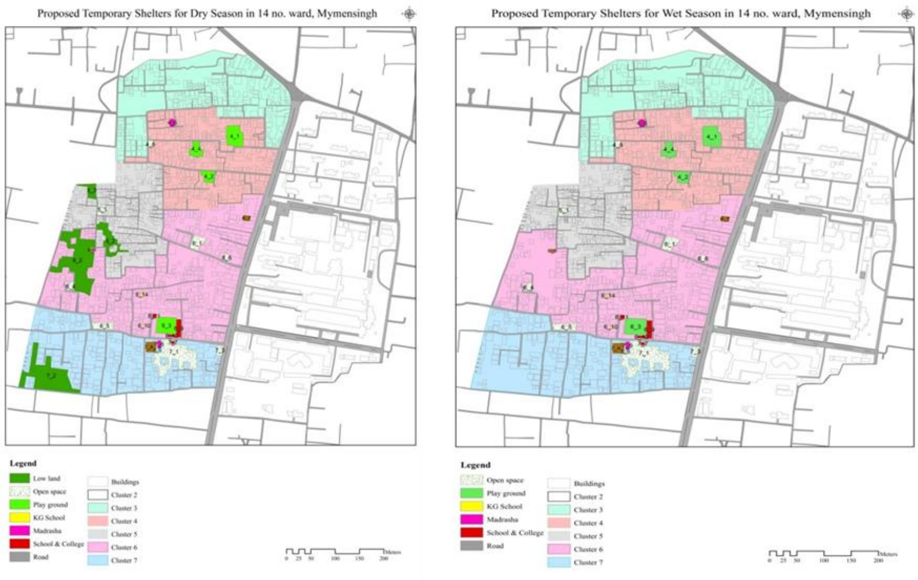


Figure 1.1: Proposed contingency plan for dry and wet season in Ward-14 of Mymensingh Pourashava

From this research it was realized that earthquake vulnerability assessment of an area is required to identify the earthquake risks of an area and take precautionary measures to minimize them. A contingency plan based on the result of vulnerability is the pathway to raise awareness among the residents. This contingency plan is neither a standalone document nor a static document. It should be an ongoing process integrated and coordinated with activities of other documents.

1.1.2 Experience from Comprehensive Disaster Management Programme, Phase II

An Earthquake Contingency Plan for Tangail and Rangpur municipal area is developed through a collaborative effort among city-level disaster management and first responder agencies as well as other relevant agencies, departments and organizations under the Comprehensive Disaster Management Programme, Phase II, in 2014. The plan aims to minimize the adverse effects of potential earthquakes by establishing and implementing a holistic response framework at town level. In April 2014, the municipality organized a training workshop on preparation of contingency plan with regard to earthquake in participation of the working group members. The results of the earthquake risk assessment and potential losses and damages for Tangail Municipality area conducted under CDMP-II and the city-level Contingency Planning template developed under CDMP-I in 2009 and revised under CDMP-II in 2012 were supplied to the group in the workshop.

A validation sensitization workshop was organized with participation of all city-level stakeholders to ensure that the plans addressed all emergency activities and issues concerns. This Contingency plan was divided into three phases: Preparation phase, Immediate Response Phase and Later Response and Recovery Phases. Preparation phase includes action strategies before the strike of earthquake. Immediate response phase incorporates the activities within initial 72 to 96 hours after a major earthquake event. Operational activities and institutional set up under city level executive committee were in this stage. Later response and recovery phase involves the activities after 72 hours some city level advocacy and plan institutionalization are on there. Moreover, estimation of resource needs and analysis of resources availability were also done considering search and rescue, immediate evacuation space, evacuation routes, fire control, health facilities, emergency shelter, relief service and transportation under this plan (CDMP, 2014).

1.2 History of Earthquake

As Bangladesh is located adjacent to the borders of Indian, Burmese and Eurasian plates and is susceptible to frequent earthquakes. Besides, The country is located close to the very active Himalayan front and ongoing deformation in nearby parts of south-east Asia expose it to strong shaking from a variety of earthquake sources that can produce tremors of magnitude 8 or greater (CDMP, 2009). Historical seismicity within Bangladesh indicates that potential for damaging moderate to strong earthquakes exist throughout much of the country (CDMP, 2009). Chittagong, Sylhet, Dhaka, Rangpur, Bogra, Mymensingh, Comilla, Rajshahi are very much vulnerable to a major earthquake disaster (CDMP, 2009). During the last 150 years, Bangladesh faced seven earthquakes of large magnitude (Richter magnitude $M \geq 7.0$) with epicenters in India and Bangladesh (Al Hussaini, 2016). Other than that Bangladesh has regularly faced many small earthquakes. Rangpur is located on active Dauki fault. Besides, Bogra fault line which was active in Palaeogene and Neogene times is very adjacent to the district of Rangpur. Deposition of huge sedimentary pile around Bogra area is evident for this fault (Zaman and Monira, 2017).

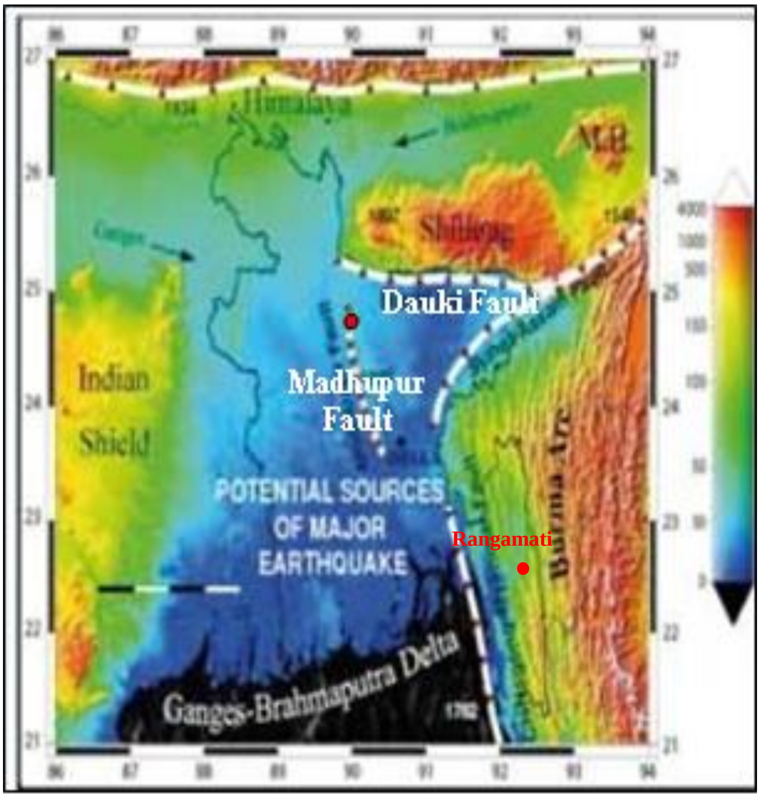


Figure 1.2: Proximity of study area to major fault lines

(Source: Akhter, 2010)

1.2.1 Earthquake Vulnerability in Rangamati Pourashava

The Chittagong Hill Tracts is originated because of the collision between India and Asia. Later India broke apart from Australia from the indo Australian plate and started to drift north northeasterly. That is the time when the history began for the Chittagong Hill Tracts (Chowdhury, 2013)

Rangamati is located at vulnerable seismic zone near the Sitakunda-Teknaf fault line, Chottogram- Mayanmar plate boundary, and Rangamati-Barkal fault. According to Revised Seismic Zoning Map of BNBC Rangpur belongs to Seismic Zone 3 with a Peak Ground Acceleration of the study wards, which range between 0.33-0.39 (Figure 1.3). Another notable feature is that Rangamati district has very high elevation from ground and the elevations change very sharply and suddenly which worsen the vulnerability scenario of the area (Source: CHTDF, 2010).

Figure 1.3: Revised Seismic Zoning of Bangladesh

(Source: HBRI, 2015)

Rangamati faced a severe earthquake of magnitude 5.1 in 27 July 2003 at Barkal Upazila of the district. Its origin was at 28 km northwest of Rangamati district. Three people were killed, 25 were injured, and hundreds of buildings of Chattogram and the surrounding hilly area were damaged. Many katcha and pucca structure showed crack, even earthen ground was ruptured in some place of Kolabunia union. Two to three kilometres of Karnafuli riverbank was demolished (Figure: 1.4).

Figure 1.4: Damage of earthquake in Kolbunai, Rangamati after 2003 earthquake

(Source: Ansary *et al*., 2003)

1.3 Aim and Objectives of the Project

1.3.1 Aim of the Project

The aim of the assignment is "building earthquake resilient community through vulnerability assessment, capacity and awareness building and promoting safe construction practices".

1.3.2 Objective of the Project

The objective of the assignment is to formulate community-based earthquake preparedness and management plan in Rangpur City Corporation and Tangail, Sunamganj and Rangamati Pourashavas. The task includes participation of community and engagement of their intuitions in assessment, planning, capacity and awareness building.

1.4 Scopes of the Project

The scope of the project involves assessment of earthquake vulnerability and response capacity of Rangpur City Corporation and Tangail, Rangamati and Sunamganj pourashavas. The contents of training on earthquake preparedness would be prepared for trainers and training would be also imparted in this assignment. Guidelines for Risk Sensitive Land Use Planning based on the vulnerability assessment would be developed with Ward Level Risk Reduction Action Plan. Ward and household level Contingency Plan would be developed with household level information. To facilitate awareness campaign in an inclusive manner, education and communication materials would be prepared. Adequate policies would be identified for proper building approval, building code enforcement and construction monitoring by the local government.

It should be mentioned here that the proposal for institutional set up for different components of the contingency plan as well as household level contingency plan would be covered in the first volume of the report.

1.5 Organization of the Report

There are seven chapters in this report. In chapter one, background, and objectives of the research have been discussed. Chapter two focuses on the profile of study area including the geographic, demographic and other characteristic of the study area. Chapter three describes the sequential steps of methodology through which the aim and objectives of this research have been achieved. Chapter four and five describes the assessment results of seismic exposure and building vulnerability of the study area. Chapter six includes very preliminary stages of earthquake contingency planning. Chapter seven concludes with some future scopes of this contingency plan during and after an earthquake event.

CHAPTER 2: STUDY AREA PROFILE

Rangamati Pourashava is situated at Rangamati district in Chittagong division, which is located on the Seismic Zone-3 of Bangladesh (Figure 1.1). The Pourashava was established in 1972 with an area of 64.72 sq. kilometer. The population of this area is 78,587 and the population density is 1214.26 person per sq. kilometers (Rangamati Pourashava). Among the 9 wards of Rangamati Pourashava, Ward no. 9 has been selected as one of the study areas for this project.

2.1 Location of the Study Area

It is located at the central east side of the Pourashava (Figure 2.1). Figure 2.1 shows the location of the Rangamati Pourashava in Rangamati district well as the Ward map of Ward 9.

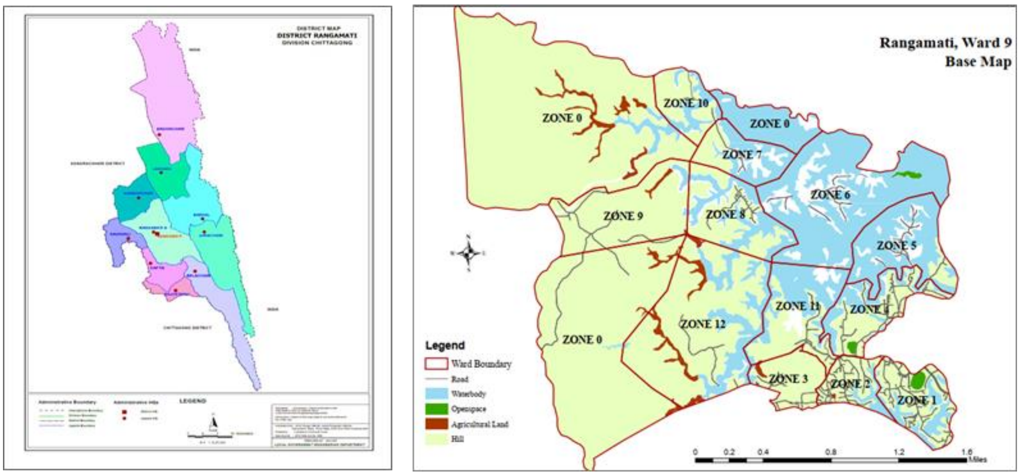


Figure 2.1: Location Map of the study area

2.2 Demographic Profile of the Study Area

The population of the Ward 9 is 1644 (BBS, 2011).The ratio of male and female population, average household (HH) size and literacy rate of Ward 9 of Rangamati pourasahava is included in Table 2.1.

Table 2.1: Male, Female ratio, and Sex Ratio of the study area

Ward No	Male (%)	Female (%)	Average Household (HH) Size	Literacy Rate (%)
9	50.2	49.8	4.9	68.6

(Source: BBS, 2011)

Table 2.2 shows the age-wise distribution of population at Ward 9 of Rangamati Pourashava which can contribute to the social vulnerability of the area. Service is the dominant occupational activities of the study area over the agricultural and industrial activities.

Table 2.2: Age-wise distribution of population at the study area

Ward No	**Percentage of Population at Different Age Group (In year)**					
	0-9	**10-19**	**20-29**	**30-49**	**50-59**	**60+**
Ward 9	21.1	24.7	16.7	24.2	6.4	6.9

(Source: BBS, 2011)

2.3 Existing Land Use of the Study Area

In the present study, data reveals that the major land use of Ward no 9 is residential and commercial (85%). Rest of the structures is used for public purposes like mosque, library and administrative activity. The road network covers a major portion of land though most of the roads are too narrow to access. A significant number of water body and open space is found in this Ward. There is also space for socio-cultural use in Ward 9.

2.4 Profile of Built Structures in the Study Area

If the structures are described according to their types it was found from survey of the present study that 24% of the structures of Ward No. 9 of Rangamati Pourashava are pucca, 22% are semi pucca and the rest are katcha. Number of stories varies from 1 to 7 among the pucca buildings. Distribution of pucca building according to their stories is shown in Table 2.3.

Table 2.3: Distribution of pucca structures according to number of storey

Number of Story	**Number of structures**
Number of 1 to 3 storied building	2088
Number of 4 to 6 storied building	46
Number of 7 or higher storied building	2
Total	**2136**

Source: (Field Survey, 2020)

Among the surveyed buildings, 63% are of residential use, followed by commercial uses (5%). Apart from these uses, some buildings are used for urban services and socio-cultural purposes. Figure 2.3 shows frequency distribution of different building uses in Ward 9 of Ragamati Pourashava.

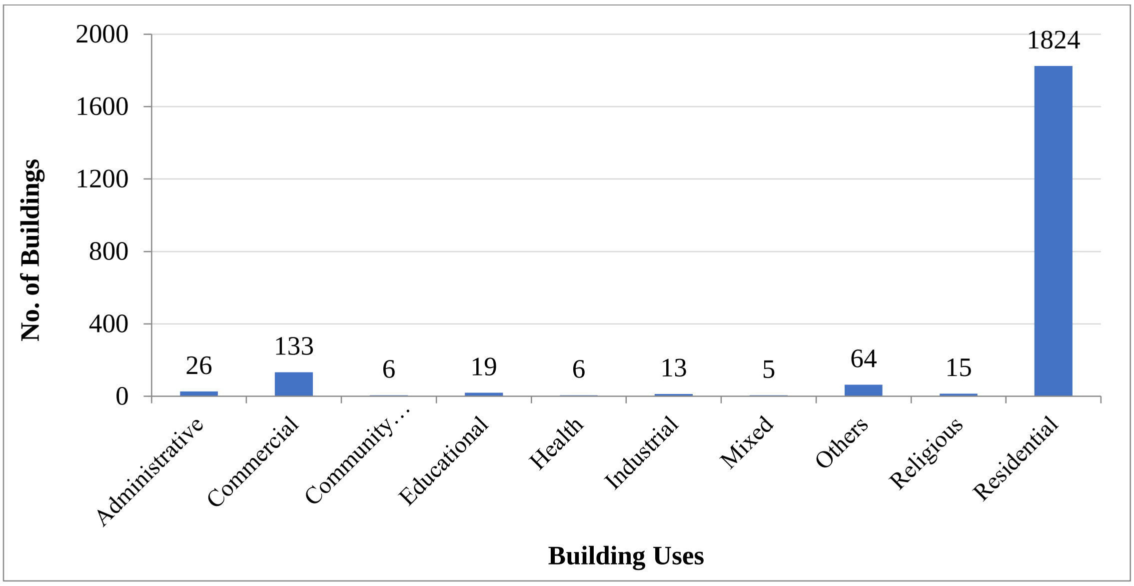


Figure 2.2: Distribution of structures according to building use

(Source: Field Survey, 2020)

There are total 72 institutional buildings in Ward 9 having both public and private ownership. Buildings for administrative purpose, educational and religious use, health facility, and community facilities have been considered as institutional building in this project. Among them, six buildings provide community facilities, twenty-six buildings are used as administrative offices, nineteen buildings are educational institutes, fifteen buildings are used for religious purpose, and six building provides health facilities.

CHAPTER 3: METHODOLOGY

3.1 Introduction

There is no unique method to determine socio-economic and building vulnerability of community due to earthquake. As contingency plan is dependent upon socio-economic and physical context, a comprehensive methodology is needed to cover the issues. Thus, a comprehensive approach has been considered in this research to prepare the earthquake contingency plan considering physical vulnerability of the area as well as socio-economic vulnerability of community. For this research, both primary and secondary data were collected. A questionnaire survey and engineering survey were conducted to understand the socio-economic context and physical vulnerability of the area and structures. In addition, secondary data on land use, institutional capacity were collected. Once the data were collected, it was verified, processed, and analyzed. In the whole process of primary data collection, local community were involved closely considering that they have better knowledge about their community and also with an aim to develop local capacity. Based on the collected data and community participation through workshop, earthquake contingency plan will be prepared. Later in this project, community-based approach will be taken for capacity and awareness building and promoting safe construction practices. The following sections provide the detail description of the methodology.

3.2 Study Area Selection

To ensure an effective response to a severe earthquake, this project has been initiated under National Resilience Programme (NRP) for Rangpur City Corporation; and Tangail, Rangamati and Sunamganj Pourashavas. All of these areas are located on severe or very severe risk seismic zone of Bangladesh (Figure 1.1) as well as there are many historical evidences of major earthquake within or close to these areas as mentioned in Chapter 1. Moreover, these areas have been opted over the whole upazila because unabated growth of human settlement and establishment of important institutions within municipal area are took place within these areas. Besides haphazard urbanization and sub-standard construction of buildings and other infrastructures without consideration of BNBC are increasing with time. In addition, the foundations and supports of structures built on the highly liquefiable sediment can fail causing damage or destruction during major earthquakes in the municipality. Poor institutional and community awareness about the risks and consequences of earthquake also exist within the selected municipalities.

Three Wards of each area were selected further by UNDP to conduct the study. These Wards were selected based on some area characteristics like: high population density, concentration of high-rise buildings with narrow lanes, lack of adequate fire extinguishers at buildings, tightly packed business center/market, lack of open space, density of educational institutions and healthcare facilities, low income community living without or lack of critical facilities etc. For convenience of contingency planning, it was also ensured that the three Wards in one area must be adjacent. Finally, twelve Wards from these four (4) areas (three from each area) were chosen based on above-mentioned criteria. For Rangamati Pourashava, Ward No. 6, 8 and 9 were selected. Among them, Ward No. 9 of Rangamati Pourashava is considered as the study area for this report.

3.3 Project Initiation

The project is initiated through inauguration workshops in an interactive way in the study area. On 14 November 2019, the initiation workshop of the National Resilience Programme was held at Rangamati Pourashava. The aim was to notify the outline of the programme. The workshop was chaired by the Honorable Mayor of Rangamati Pourashava, Mr. Md. Akbar Hossain Chowdhury. From BUET, Prof. Dr. Raquib Ahsan, Prof. Dr. Shakil Akhter, Ms. Uttama Barua, Ms. Tasnim Tarannum Isaba and Ms. Shamontee Aziz attended the workshop. Officials from UNDP along with the Project Director of NRP were also present. District Commissioner of Rangamati Hill District along with other officials from district administration, ward councilors, officials from other government departments, NGOs working in disaster management, volunteers from Girls Guide, Bangladesh Scout and Bangladesh Red Crescent Society and members of civil society attended the workshop.

Vulnerability context of Rangamati Pourashava and possible activities under the project were presented by BUET and UNDP team. There was an open discussion where the role and responsibilities of local people and officials for earthquake preparedness were discussed.

Figure 3.1: Inauguration Workshop

3.4 Secondary Data Collection

For the purpose of this project, data were collected from different secondary sources. From Rangamati Pourashava office, the GIS database of the study area was collected, which is the main basis for this project. It contains data on area boundary, structures type, land use and road network. This database was used to prepare the base map of the study area. The database was last updated in the year of 2013. Considering the huge development in the study area from 2013 to 2019, it was necessary to verify and update the database. In this regard, Google Earth satellite image of the study area was collected and utilized, where the latest images were available for the year 2018. At the preliminary stage, the land cover and in some cases land use were identified by using Google Earth tag. Additionally, the newly built structures, water bodies, open spaces, barren lands etc. were digitized. In this way, the GIS database of the study area was primarily updated based on satellite image. From the update, it had been found that almost 400 new buildings were constructed in between 2013-2018.

Data on socio-demographic profile of the study area were collected from Rangpur Pourashava website. Some policy documents such as Building Construction Rules (1996) and project reports such as Earthquake Risk Reduction and Recovery

Preparedness Programme in Chittagong Hill Tracts Area (CHTDF, 2010) for Rangamati Pourashava were collected and reviewed to identify the previously collected data on development pattern, soil characteristics etc. of the study area.

3.5 Primary Data Collection

For this project, primary data were collected, which included physical observation survey for GIS database verification and updating, Standard Penetration test and microtremor test for assessment of seismic exposure, preliminary vulnerability assessment of buildings through Rapid Visual Screening (RVS) method, household questionnaire survey and checklist survey for social vulnerability assessment and contingency planning for earthquake, and detailed vulnerability assessment of buildings through Details Engineering Assessment (DEA). Primary data collection methods are described in the following sections:

3.5.1 Primary Data Collection for GIS Database Verification and Updating: Physical Observation Survey

The preliminary updated GIS database based on Google Earth satellite image was finally verified and updated through physical observation survey. Here, the preliminary updated GIS database was utilized to prepare the base maps to be verified and updated. For ease of data collection and planning, the study area was divided into 18 clusters in consultation with local people considering the area of the clusters and the density of structures in the clusters. Appendix A shows the designated clusters in the study area. These clusters were utilized throughout this project for data collection, assessment, and earthquake contingency planning. Thus, cluster wise base maps were prepared utilizing preliminary updated GIS database to carry out the physical observation survey.

Through physical observation survey, it was intended to verify and update data on the location of the water bodies, open spaces, barren lands, and road network, etc. as well as the building information. To collect data of building information, a checklist was prepared which is shown in Appendix B. The attributes considered include detailed building use, type of structure, number of storey, width of adjacent road, etc. To ensure digital data collection and real time data management, “KoBo Toolbox” was utilized for data collection. Thus, after preparation of the checklist, it was prepared in “KoBo Toolbox” and was tested to ensure workability.

After preparation of base maps and checklist in “KoBo Toolbox”, the physical observation was conducted from December 2, 2019 to December 20, 2019. For the purpose of data collection in the study area, nine groups were formed consisting of two members each. These surveyors were local volunteers from Boy Scouts, Girls’ Guide, and Red Crescent Society of Rangamati District. These groups were supervised by research assistants and technical officials from BUET to ensure accuracy in data collection.

Once the field survey was completed, the preliminary updated GIS database was updated and finalized incorporating all the collected data. According to the updated database, there are total 425 pucca structures, and 1833 katcha and semi-pucca structures in the study area.

3.5.2 Primary Data Collection for Assessment of Site-Specific Seismic Hazard

In order to assess the site-specific seismic hazard of the study area, two bore holes up to a depth of 30 meters were conducted in the study area. Disturbed and undisturbed samples were also collected from different depths. Figure 3.2 shows the location of the bore holes.

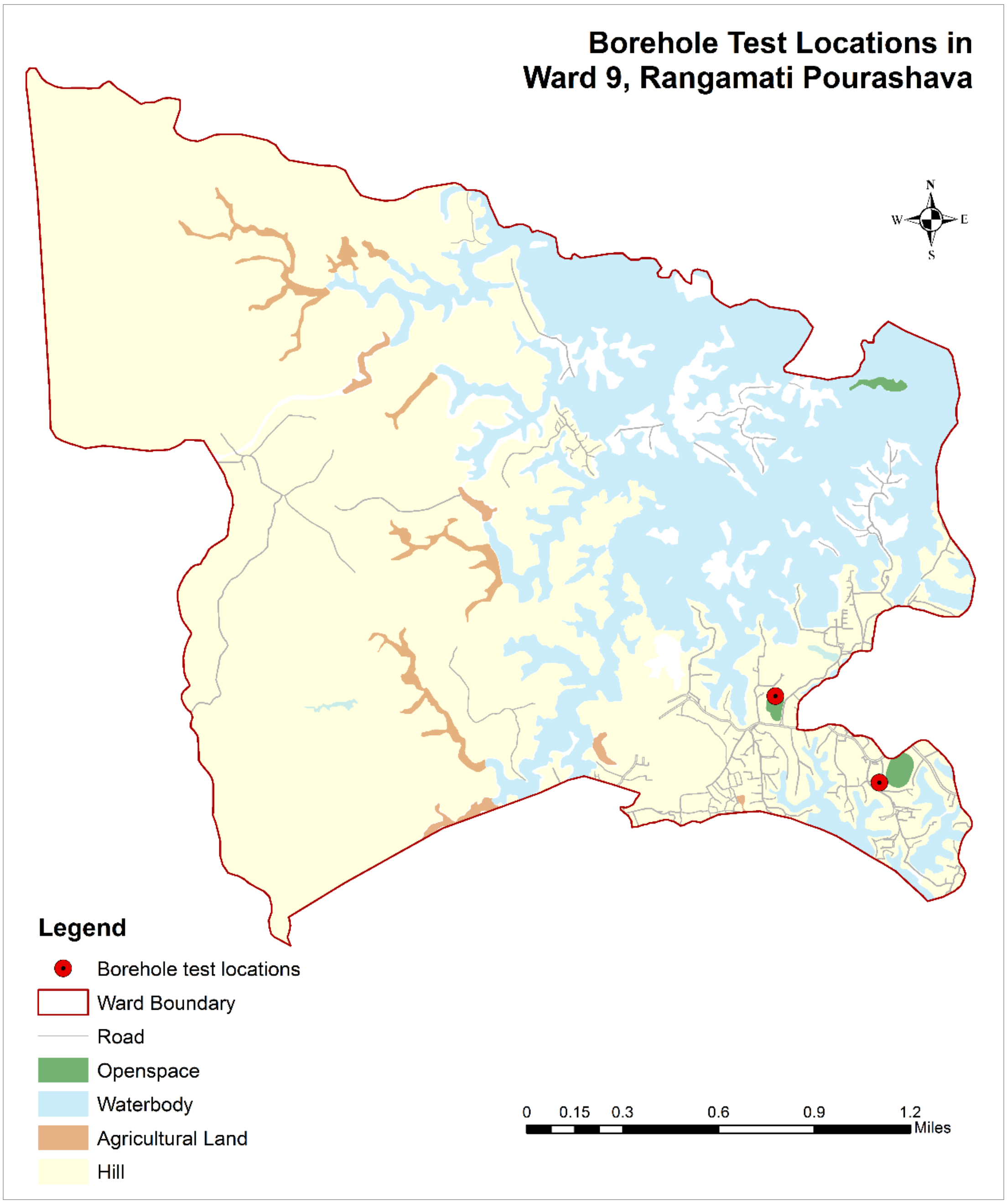


Figure 3.2: Location of boreholes

Microtremor tests were conducted using five velocity sensors each having three channels. The channels collected data in north-south, east-west and up-down directions. For each sensor the X axis was aligned with north. Each sensor was placed 25 meters apart. Precautions were taken to avoid noises and vibrations from other external sources so that they do not hamper the recording of the ambient vibration. Figure 3.3 shows the location of Microtremor tests in the study area (Ward No.9, Rangamati Pourashava). These tests were conducted on March, 2021.

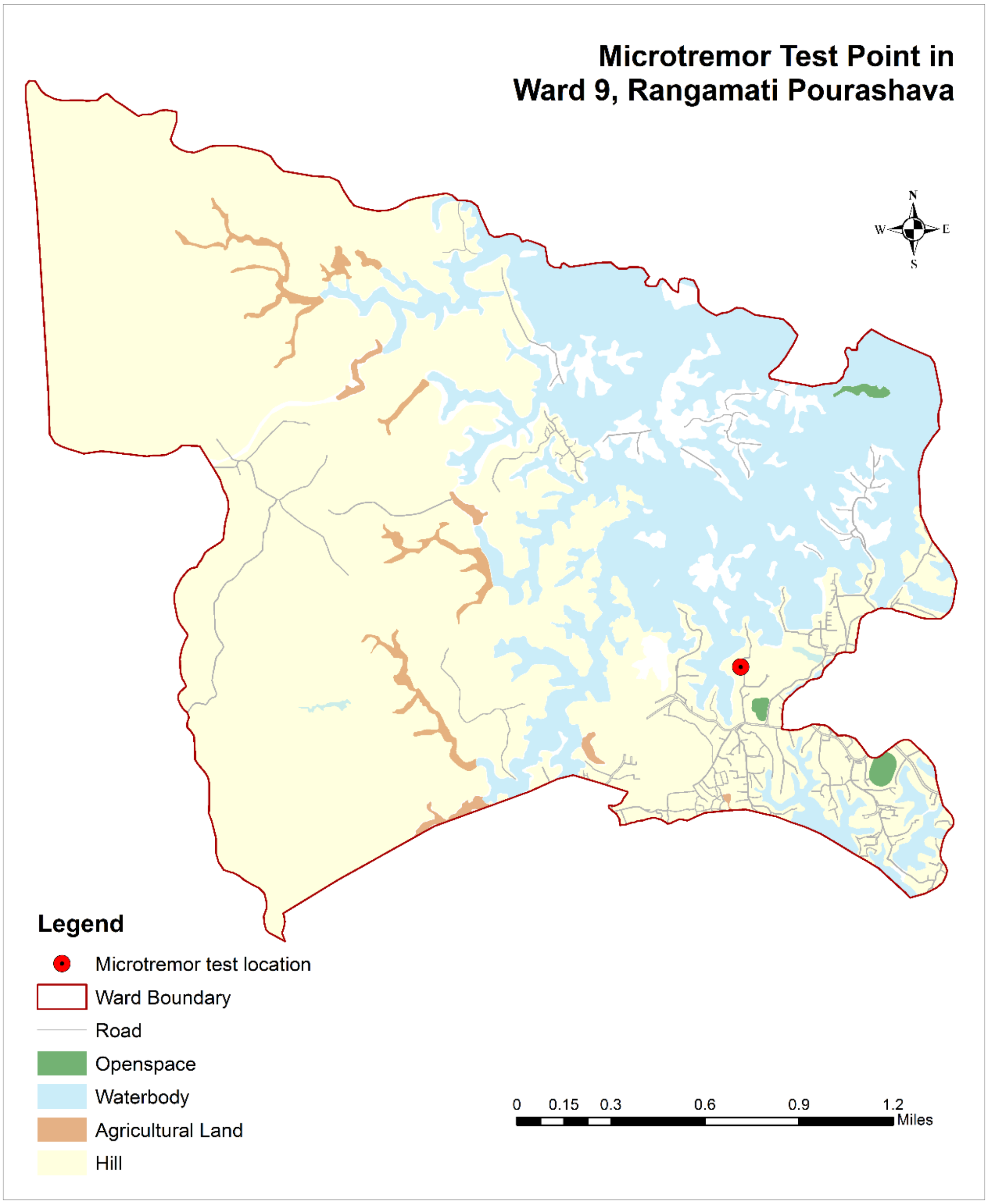


Figure 3.3: Microtremor test location

3.5.3 Primary Data Collection for Preliminary Vulnerability Assessment of Buildings: Rapid Visual Screening (RVS) Method

To assess the preliminary vulnerability of the buildings in the study area, Level 1 survey of RVS (Rapid Visual Screening) suggested by FEMA (Federal Emergency Management Agency, USA, 2017 edition) was adopted. Rapid Visual Screening

(RVS): FEMA P-154 was developed by ATC (Applied Technology Council) on behalf of FEMA. Its purpose is to provide a methodology to evaluate the seismic safety of a large inventory of buildings quickly and inexpensively, with minimum access to the buildings, and determine those buildings that require a more detailed examination (FEMA, 2017). It is a sidewalk survey process that enables to classify the surveyed buildings into two categories: those that may not pose risk to life and those that may be seismically hazardous and should be investigated in more details by a design professional experienced in seismic design.

To collect data in this regard, firstly sample size was determined, the base maps and form for data collection was prepared and finally the related data were collected. These methods are described below:

3.5.3.1 Sampling of Buildings

According to the contract between DDM and BUET, the total sample size in this regard from all the study areas of this project (Section 3.2: Study Area Selection: Total 12 Wards in three Pourashavas and one City Corporation consisting of three Wards each) would be 2000 pucca buildings. Considering the human error in data collection process, BUET team decided to collect data from 2207 pucca buildings. The sample buildings were distributed in 12 Wards (Section 3.2: Study Area Selection: three Pourashava and one City Corporation consisting of three Wards each) through proportional distribution based on number of pucca buildings in each Wards accordingly (considering updated databases). Thereby, the sample size in the study area of this report (Ward No. 8 of Rangamati Paursahava) for preliminary vulnerability assessment through RVS method was found total 77 pucca buildings. For selection of these 77 sample pucca buildings in the study area, the following three criteria were considered.

a) Institutional and administrative uses: Here all the government administrative offices and institutional facility buildings (including health, educational, religious and community facility) were labeled as institutional and administrative buildings and the rest were considered as buildings of other uses. All of the buildings from this category irrespective of their number of storey were selected for preliminary vulnerability assessment. These buildings will be considered in contingency planning purpose for disaster shelter, emergency health facility and Ward Co-ordination Center.

b) Buildings of other uses with number of storey 4 or more: All of the buildings falling within this category were considered for preliminary vulnerability assessment. If these buildings collapse or damage after an earthquake, they may create debris blocking the roads and thus hampering emergency management after an earthquake.

c) Buildings of other uses with number of storey 1 to 3: Rest of the sample buildings were selected from this category. Representation from all of the clusters in the study area was ensured through proportional distribution of the sample size. The sample buildings within this category were selected arbitrarily through discussion with local people.

Table 3.1 shows sample size of buildings selected from different categories with respect to total number of buildings, for preliminary vulnerability assessment through RVS method. Table 3.2 shows the number of samples in each cluster of the study area.

Table 3.1: Sampling of pucca buildings for preliminary vulnerability assessment through RVS method

Building use	**Institutional and Administrative**		**Other uses**			**Total**
Number of storey	**1-3 Storey**	**3+ Storey**	**1-3 Storey**	**4-6 Storey**	**6+ Storey**	
Sample size	30	5	30	12	0	**77**
	35		42			

Table 3.2: Number of samples in each cluster

Cluster No.	Building use		Total sample
	Institutional and Administrative	**Other uses**	
1	6	13	19
2	7	8	15
3	2	14	16
4	0	0	0
5	1	2	3
6	2	0	2
7	3	4	7
8	2	3	4
9	9	0	9
10	0	0	0
11	0	0	0
12	0	0	0
Total	**34**	**43**	**77**

3.5.3.2 Base Map and RVS Form Preparation

After sample size determination, base maps indicating the sample buildings were prepared in ArcGIS based on updated GIS database. For convenient and organized data collection, cluster wise base maps were prepared accordingly showing the sample buildings.

For preliminary vulnerability assessment of the sample buildings of the study area through RVS method (Level 1) the form recommended by FEMA was utilized (Appendix C). To ensure digital data collection and real time data management, “KoBo Toolbox” was utilized for data collection. Thus, the form of FEMA for RVS (Level 1) survey was prepared in “KoBo Toolbox” and was tested to ensure workability. The attributes included in this form are: the building identification information, picture of building, information of use, floor area, number of story as well as some pertinent data related to seismic performance e.g. vertical irregularity, seismic force resisting system, structural materials of the buildings, plan irregularity, pounding potential and the effect of surrounding structure, geological features on the site, non-structural hazards etc..

3.5.3.3 Data collection

After preparation of the cluster wise base maps showing sample buildings and the RVS (Level 1) form in “KoBo Toolbox”, the preliminary building vulnerability assessment survey was conducted from March 2, 2021 to March 05, 2021 (Figure 3.4). For the purpose of data collection in the study area, three groups were formed consisting of two members each. These surveyors were local volunteers who are mostly undergraduate student with science background. These groups were supervised by technical officials from BUET to ensure accuracy in data collection.

Figure 3.4: A group headed by a technical person during fieldwork

3.5.4 Primary Data Collection for Social Vulnerability Assessment and Contingency Planning for Earthquake: Household Questionnaire Survey

To collect data for social vulnerability assessment and preparation of earthquake contingency planning for the study area, household questionnaire survey was conducted. To collect data in this regard, firstly, sample size was determined, the base maps and questionnaire for data collection were prepared, and finally the related data were collected. These methods are described below:

3.5.4.1 Sampling of Households

According to the contract between DDM and BUET the total sample size in this regard from all the study areas of this project (Section 3.2: Study Area Selection: Total 12 Wards in three Pourashavas and one City Corporation consisting of three Wards each) would be 2000 households. Considering the human error in data collection process, BUET team decided to collect data from 2200 household. For appropriate representation and to avoid repetition, it was considered that one sample household would be selected from one residential structure. Thus, the total 2200 sample residential structures (representing one sample household each) were distributed in 12 Wards (Section 3.2: Study Area Selection: three Pourashavas and one City Corporation consisting of three Wards each) through proportional distribution based on number of residential structures in each Wards accordingly (considering updated databases). Thereby, the sample size in the study area of this report (Ward No. 9 of Rangamati Pourashava) for household questionnaire survey was found total 114 households from 114 residential structures. For selection of these 164 residential structures in the study area, two following criteria were considered.

a) Residential buildings with number of storey 4 or more: All four storied or higher residential buildings in the study area were considered to select sample households (one from each) for household questionnaire survey. If these buildings collapse or damage after an earthquake, they may create debris blocking the roads and thus hampering emergency management after an earthquake. This will make implementation of the contingency plan more challenging. Therefore, representation from these buildings was considered a must.

b) Residential buildings with number of storey 3 or less, and katcha and semi pucca residential structures: The remaining sample buildings were selected from these two categories proportionally to ensure representation of households from these buildings and structures. Representation from all of the clusters in the study area was ensured through proportional distribution. The sample buildings within this category were selected arbitrarily through discussion with local people.

The decision for retrofitting of residential buildings (if necessary) would depend on perception of building owners. Therefore, it was necessary to consider the owner's households for the household questionnaire survey. Again, the tenants would also respond and suffer the impact of an earthquake in their area. Hence, the perception of the tenants was also necessary to be understood. Paying attention to this issue, proportion for distribution of households of owners and tenants within the determined sample size was considered 70% and 30% accordingly. Thus, after determination of the sample size of buildings representing one sample household each for household questionnaire survey, they were distributed among owners and tenants considering the above-mentioned proportion. To ensure representation from all of the clusters in the study area, owner's and tenant's sample households were determined from different clusters proportionally.

Table 3.3 shows sample size of buildings selected from different categories with respect to total number of buildings for household questionnaire survey along with their proportion among owners and tenants. Table 3.4 shows the number of samples in each cluster of the study area.

Table 3.3: Sampling of residential buildings for household questionnaire survey

Number of storey	**Katcha and Semi Pucca**	**Pucca 1-3 Storey**	**Pucca 4-6 Storey**	**Pucca 6+ Storey**	**Total**
Total sample size	67	11	32	3	**114**
Sample size for owners (70% of total sample size)	47	8	22	2	**79**
Sample size for tenants (30% of total sample size)	20	3	10	1	**35**

Table 3.4: Cluster wise sampling of residential buildings for household questionnaire survey

	Katcha and Semi Pucca			**Pucca 1 to 3 Storied**			**Pucca 4 to 6 Storied**			**Pucca 6+ Storied**			**Total**		
	Owner	Tenant	**Total**	Owner	Tenant	**Total**	Owner	Tenant	**Total**	Owner	Tenant	**Total**	Owner	Tenant	**Total**
Cluster 1	0	0	**0**	0	0	**0**	1	0	**1**	0	0	**0**	1	0	**1**
Cluster 2	7	3	**10**	2	1	**3**	5	3	**8**	0	0	**0**	14	7	**21**
Cluster 3	7	3	**10**	0	0	**0**	4	3	**7**	0	0	**0**	11	6	**17**
Cluster 4	7	3	**10**	0	0	**0**	0	0	**0**	0	0	**0**	7	3	**10**
Cluster 5	4	2	**6**	0	0	**0**	2	0	**2**	0	0	**0**	6	2	**8**
Cluster 6	7	3	**10**	3	1	**4**	2	0	**2**	0	0	**0**	12	4	**16**
Cluster 7	4	2	**6**	0	0	**0**	1	1	**2**	0	0	**0**	5	3	**8**
Cluster 8	7	3	**10**	3	2	**5**	2	1	**3**	2	1	**3**	14	7	**21**
Cluster 9	4	1	**5**	0	0	**0**	5	2	**7**	0	0	**0**	9	3	**12**
Cluster 10	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**

	Katcha and Semi Pucca			Pucca 1 to 3 Storied			Pucca 4 to 6 Storied			Pucca 6+ Storied			Total		
	Owner	Tenant	**Total**	Owner	Tenant	**Total**	Owner	Tenant	**Total**	Owner	Tenant	**Total**	Owner	Tenant	**Total**
Cluster 11	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**
Cluster 12	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**	0	0	**0**
Total	**47**	**20**	**67**	**8**	**4**	**12**	**22**	**10**	**32**	**2**	**1**	**3**	**79**	**35**	**114**

3.5.4.2 Base Map and Questionnaire Preparation

After sample size determination, base maps indicating the sample buildings (specifying owners' and tenants' households) were prepared in ArcGIS based on updated GIS database. For convenient and organized data collection, cluster wise base maps were prepared accordingly showing the sample buildings.

Firstly, a draft questionnaire was prepared for collection of data for household questionnaire survey based on review of different related literatures. While preparing the questionnaire the following issues were taken into consideration: the general information of the respondent and household, respondent's awareness, knowledge and perception on earthquake, respondent's ideas about earthquake disaster management, and owner's consent to earthquake risk reduction. After preparation of the draft questionnaire, pilot surveys were conducted for six households in Tangail Pourashava on 9th December, 2019 (during the physical observation survey in Tangail Pourashava). The purpose of the pilot surveys was to check the consistency, to identify the complexities or gaps of the questionnaire, and to develop the mechanism and approach for the survey. After the piloting, the questionnaire was finalized addressing the shortcomings accordingly which is shown in (Appendix D). Household questionnaire survey was completed in Tangail Pourashava and Rangpur City Corporation. Therefore, the same finalized format of questionnaire used in Tangail and Rangpur was also used in Rangamati. To ensure digital data collection and real time data management, "KoBo Toolbox" was utilized for data collection. Thus, after preparation of the final questionnaire, it was prepared in "KoBo Toolbox" and was tested to ensure workability.

3.5.4.3 Data collection

After preparation of the cluster wise base maps showing sample buildings and the questionnaire in "KoBo Toolbox", the household questionnaire survey was conducted in the study area from March 2, 2021 to March 05, 2021 parallel with the preliminary building vulnerability assessment survey (Figure 3.5). For the purpose of the survey, six groups were formed consisting of two members each. These surveyors were local volunteers (students). These groups were supervised by research assistants and technical officials from BUET to ensure accuracy in data collection.

Figure 3.5: Data Collection-Household Survey

3.5.5 Primary Data Collection for Contingency Planning for Earthquake: Checklist Survey

For contingency planning for disaster shelter and emergency health facility, it was necessary to collect basic data about the facilities potential to be used for this purpose. In this regard, checklist survey was necessary to be conducted for potential disaster shelters (educational facilities, religious facilities, community centers, etc.) and emergency health facilities (hospital, clinic, and other health facilities). In this regard, firstly relevant checklists were prepared to collect data from different facilities in the study area accordingly. These checklists are given in Appendix E. After preparation of the checklists, the checklist surveys were conducted in the study area from March 2, 2021 to March 05, 2021 parallel with preliminary building vulnerability assessment and household questionnaire survey.

3.5.6 Training of the Volunteers for Data Collection

Local community plays the role of first responders in case of any disaster. Therefore, strategies for local empowerment and capacity building are needed in order to ensure effective disaster mitigation (Shaw, 2012). Moreover, local people are familiar with their locality and have greater knowledge about their community. Due to their local residency, community people have greater trust on them and they feel at ease to respond to them. Thus, community-specific training programme is an important tool which utilizes local knowledge and enhances the potential of local residents (Rivas and Kilmer, 2016). Considering these, one of the goals of the project is to engage the people of the community in all the phases in order to build their capacity. Therefore, in this project local people were involved in the whole process of data collection for GIS database verification and updating, preliminary building vulnerability assessment and household questionnaire survey. To involve them in the process, their capacities were developed through training programs. The training programs conducted in the study area for capacity building of local people the data collection at different phases in this project are discussed below:

3.5.6.1 Training on Data Collection for GIS database Verification and Updating

This training program was organized on 2nd December, 2019 (Sunday). The criteria for participating in the data collection process was that the volunteers should be educated (student or graduate) and should have active android smart phones capable of operating "KoBo Toolbox". On 2nd December, 2019 (Sunday), an interactive training session was organized at Rangamati Paursahava office (Figure 3.6). The session started at around 10.00 a.m. It was attended by members from Boy Scouts, Girls' Guide, and Red Crescent Society of Rangamati District. The volunteers were instructed by four (4) technical officials and two (2) research assistants of BUET-JIDPUS. At the initiation of the training program, firstly the participants and the instructors were introduced to each other. After that, the instructors presented a presentation explaining the project background and how it would help the local people to address earthquake risk in their area, rationale for selecting the study area in Rangamati Pourashava, and the purpose and importance of the physical observation survey for verification and updating the GIS database for the project. Then the volunteers were trained regarding the survey procedure, i.e. how to read the base maps, introduction, and explanation of different variables in the checklist for data collection, and the process of data collection using "KoBo Toolbox" mobile application. This training session was interactive, where the volunteers asked questions for necessary clarification. At the end of the training, the volunteers were divided into nine groups to carry out the physical observation survey for data collection in the study area for GIS database verification and updating.

Figure 3.6: Training of local volunteers regarding the map updating process

3.5.6.2 Training on Data Collection for Preliminary Building Vulnerability Assessment and Household Questionnaire Survey

For convenience of work, it was intended to carry out the preliminary building vulnerability assessment and household questionnaire survey simultaneously. Therefore, the training programs for preliminary building vulnerability assessment and household questionnaire survey were organized together, which was organized on 1st March, 2021. Due to the pandemic condition, the training session was conducted online through Zoom platform. Technical staffs of BUET-JIDPUS facilitated the program being physically present in Rangamati whereas BUET officials and research assistants joined with them in Zoom meeting. It was estimated that six groups would be required to be formed consisting of two members each for preliminary building vulnerability assessment survey. The criteria for the volunteers for this survey were: should have civil engineering knowledge, educated (student or graduate) and should have active android smart phones capable of operating “KoBo Toolbox”. Similarly, six groups were estimated to be formed consisting of two members each for household questionnaire survey. The criteria for the volunteers for this survey were: should have capacity to communicate with people, educated (student or graduate) and should have active android smart phones capable of operating “KoBo Toolbox”. In this regard, one week before the training program, local representatives were contacted to communicate and organize local volunteers interested to involve in the data collection process accordingly fulfilling the criteria.

Figure 3.7: Training program to conduct data collection for preliminary building vulnerability assessment and household questionnaire survey

On 1st March 2021, at 11.30 am the training program was organized in Rangamati Paurshava Office (Figure 3.7). Considering the criteria, total 18 volunteers participated in the training program for preliminary building vulnerability assessment survey, these surveyors were local volunteers who were mostly undergraduate students with science background. These groups were supervised by technical officials from BUET to ensure accuracy in data collection. Another 18 volunteers (students) participated for household questionnaire survey. The training program was conducted by the faculty members, research assistants, and technical officials from BUET.

The program consisted of three sessions. The first session was the formal inauguration. Firstly, the participants and the instructors were introduced to each other. A presentation on brief summary of the project and the objective of the work was given. by the instructors. The presentation explained the project background and how it would help the local people to address earthquake risk in their area, rationale for selecting the study area in Rangpur, and the purpose and importance of the preliminary building vulnerability assessment and household questionnaire survey. At the end of this session, a lecture on map reading was given. Here the base maps were introduced to the volunteers and they were instructed how to locate the selected buildings which were to be surveyed by reading the map.

After the formal inauguration, the volunteers for preliminary building vulnerability assessment and household questionnaire survey were separated in two different Zoom meeting. Both of these trainings were interactive, where the volunteers asked questions for necessary clarification. In the training session on preliminary building vulnerability assessment, the participants were introduced to the Rapid Visual Screening (RVS) survey method, the survey form with explanation of different variables and the process of data collection using "KoBo Toolbox" mobile application. In the training session on household questionnaire survey, the participants were introduced to the survey method, the questionnaire with explanation of different variables and the process of data collection using "KoBo Toolbox" mobile application.

After the second session, the third session was started which was also separate and parallel. It was an interactive session where demo preliminary building vulnerability assessment and household questionnaire survey were conducted in the field. For demo preliminary building vulnerability assessment through RVS method, the volunteers were taken to sample buildings and a hands-on demonstration of the survey was conducted. For demo household questionnaire survey, the volunteers were asked to carry out the questionnaire survey among themselves to have a clear understanding of the survey and different variables. Later demo household questionnaire survey was conducted in a few households of the study area.

3.5.7 Primary Data Collection for Detailed Vulnerability Assessment of Buildings: Details Engineering Assessment (DEA)

Based on the preliminary building vulnerability assessment and as per requirement for contingency planning, some buildings will be selected in the study area for Detailed Engineering Assessment (DEA). For this purpose, some destructive and non-destructive test and measurements will be taken in the buildings for checking design requirements of the BNBC. They are:

a) Two (02) boreholes up to 100 ft. the depth and undisturbed soil samples will be collected and Microtremor tests will be done.

b) Detail dimensions (dimension of the buildings, room, kitchen, toilets, door, windows, and floor to floor height etc.) will be collected.

c) Ferro-scanning tests will be performed. At the same time, cores from the columns, beams and slabs may be collected.

d) Footings will be excavated for dimensions. In case of masonry buildings shear test of masonry buildings will be performed.

3.6 Assessment of Seismic Exposure

The collected borehole data and undisturbed soil samples were analyzed and plotted to understand the seismic exposure of the study area. Microtremor test data were analyzed and plotted to know dynamic characteristics of soil in the study area.

3.7 Building Vulnerability Assessment

3.7.1 Preliminary Assessment: RVS Method

Based on collected data, a score for each of the buildings surveyed was calculated following methods of RVS. It indicates the seismic performance of the buildings. The scores are based on the probability of building collapse and average expected ground shaking levels for the seismicity region (FEMA, 2015). A cut-off score is suggested based on the present seismic design criteria. If the building's score is less than the cut-off score, the buildings should be investigated by a design professional experienced in seismic design. If a building receives a score higher than cut-off score, the building is considered to have adequate seismic resistance to prevent collapse during a rare earthquake. The score is not meant to be an indicator of the probability that the building will be usable following an earthquake (FEMA, 2015). Seismic evaluation and retrofit of existing buildings will be most appropriate for those buildings that require a detailed structural evaluation. In this research, 1.2 is considered as the cutoff score.

3.7.2 Detailed Engineering Assessment (DEA)

The borehole test data and undisturbed soil samples will be tested in the laboratory to know the site characteristics of the selected buildings. Microtremor test data will be analyzed to know dynamic characteristics of soil beneath the buildings. Based on the collected detail dimensions of the selected buildings, their as-built drawings will be prepared. From Ferroscan test, the number and size of the reinforcing bar used in column and slab will be determined. By testing the cores collected from the column of the selected buildings, the compressive strength of the used concrete will be estimated.

On the basis of footings excavation, the foundation size/dimension and condition of the footing of the buildings will be determined. Additionally, based on a shear test of masonry buildings, shear strength of the brick used in the buildings will be determined. Finally, Finite Element Analysis (FEA) through computer modeling will be performed and the results will be compared with the collected data. This computer modeling confirms whether the buildings are good enough to withstand gravity and seismic load or strengthening (retrofitting) is required.

3.8 Social Vulnerability Assessment

After the completion of questionnaire survey, data were exported from Kobo Toolbox as an excel spreadsheet. Total 114 household questionnaires were found for the study area. Necessary analyses were performed based on the data from these 114 households. The socio-economic issues include issues like age, sex, educational level, occupation, household income, physically or mentally challenged people, house ownership etc. and the perception of the households regarding earthquake were analyzed here. Statistical analysis was performed to understand the socio-economic context of the study area. Further analysis will be carried out for social vulnerability assessment in the study area.

3.9 Contingency Planning for Earthquake

Based on building and social vulnerability of the study area, an earthquake contingency plan is expected to be prepared for the study area. The contingency plan would have four components. They are:

- Temporary Shelter Planning
- Emergency Health Facility Planning
- Evacuation Route Planning
- Identification of space for Ward Co-ordination Center

3.9.1 Temporary Shelter Planning

After an earthquake, it is expected that good number of people will be homeless due to collapse of buildings. It would be an urgent need to provide them shelter. Temporary dwellings constitute a crucial step of recovery and reconstruction in the post-disaster aftermath. It plays a vital role in order to provide protection to the affected people and provide a habitable environment while the outcomes of a disaster are being evaluated and then rectified (Donohue, 2012). Different steps of temporary shelter planning are discussed here:

a) Need Assessment (Demand Calculation for Disaster Shelter)

In this research, it has been assumed that the people residing in vulnerable buildings with probability of extensive or complete structural damage after an earthquake would require disaster shelter in the study area. Considering the assumption, firstly the vulnerable residential and mixed use (with residential use) buildings in the study area with probability of extensive or complete structural damage were estimated accordingly. From section "3.5.3 Primary Data Collection for Preliminary Vulnerability Assessment of Buildings: Rapid Visual Screening (RVS) Method" it can be observed that sample number of buildings in the study area have been assessed for building vulnerability. Now demand estimation based on scenario of the sample buildings would underestimate the demand scenario. Again, the sample size represents the population at 95% confidence level and 5% confidence interval. Therefore, the scenario of extensive or complete structural damage of sample residential and mixed use (with residential use) buildings were translated into the total residential and mixed use (with residential use) buildings in the study area proportionally with respect to number of storey of the buildings. In this way number of vulnerable residential and mixed use (with residential use) buildings with probability of extensive or complete structural damage after an earthquake in the study area were estimated with respect to number of storey.

After the identification of the vulnerable residential and mixed use (with residential use) buildings it was necessary to estimate the number of people residing in these buildings. The data on building wise occupancy were unavailable. So, occupancy per residential floor was estimated in this research. While doing so population in Ward 8 in 2020 was calculated from the population of 2011 using the annual growth rate of Rangamati District. Then total number of residential floors in the study area was estimated from all residential buildings and their corresponding number of storey, and residential floors in mixed use buildings. From total number of residential floors and total population in the study area, number of people residing per floor was estimated. Using this occupancy per floor, number of people residing in the identified vulnerable residential and mixed use (with residential use) buildings in the study area were calculated. Among them, people requiring disaster shelter were estimated based on the assumptions as per HAZUS technical manual (FEMA, 2012). The assumptions considered in this research for disaster shelter demand calculation is shown in Table 3.5. Equation 1, 2 and 3 show the formulas for six demand estimation in the study area.

Table 3.5: Assumption for disaster shelter demand calculation

Probable damage state of vulnerable residential buildings	**Factor**
Buildings with probability of extensive structural damage (F_e)	0.9
Buildings with probability of complete structural damage (F_c)	1.0

Source: Adapted from FEMA (2012)

$D_e = \sum B_e \times n \times p \times F_e$ …………………………………… (Equation 1)

Here,

D_e = Number of people requiring disaster shelter residing in vulnerable buildings with probability of extensive structural damage

B_e = Number of vulnerable buildings with probability of extensive structural damage

n = Number of residential floors in the corresponding buildings

p = Population per residential floor

F_e = Factor of disaster shelter requirement for vulnerable buildings with probability of extensive structural damage

$D_c = \sum B_c \times n \times p \times F_c$ …………………………………… (Equation 2)

Here,

D_c = Number of people requiring disaster shelter residing in vulnerable buildings with probability of complete structural damage

Bc = Number of vulnerable buildings with probability of complete structural damage

n = Number of residential floors in the corresponding buildings

P = Population per residential floor

Fe = Factor of disaster shelter requirement for vulnerable buildings with probability of extensive structural damage

D = De + Dc …………………………………… (Equation 3)

Here,

D = Total number of people requiring disaster shelter

D_e = Number of people requiring disaster shelter residing in vulnerable buildings with probability of extensive structural damage

D_c = Number of people requiring disaster shelter residing in vulnerable buildings with probability of complete structural damage

b) Available Space Assessment (Supply Calculation)

In Japan, large-park or open space, playground, religious and school buildings and spaces in public buildings are considered to provide shelter in after math of an earthquake (Xu, Okada, Hatayama, & He, 2006; World Bank Institution, 2012) while after 2015 tents in open spaces were used in Nepal as temporary shelter (Sheltercluster.org, 2018) (Figure 3.8). So for temporary shelter, open space, playground, religious and educational buildings and spaces in public building used for community facilities were considered.

Thus, all the possible temporary shelters (open space; educational/ religious institution and public building used for community facility) in the study area were identified. Here mixed use buildings were left out from consideration due to their unsuitability. The institutional buildings to be used for temporary shelter should be structurally safe. Therefore, the buildings, which deemed to be structurally unsafe according to the RVS score, were identified. In this regard, buildings with RVS score below 1.2 was considered as unsafe or vulnerable to earthquake. Estimation of space in safe and unsafe structures was done separately. This would bring out the scenario about the unsafe institutional buildings that would be made available for temporary shelter if these buildings could be retrofitted accordingly.

(a) At the Ofunato Junior High School, Japan

(b) At Army ground in Kathmandu, Nepal

Figure 3.8: Example of temporary shelter

Now, the whole area of open spaces and total floor area of building would not be usable for functional for shelter purpose. Thus, functional spaces for shelter purpose in the selected temporary shelters were calculated. For this purpose, it was assumed that 80% of the available space would be used as shelter. The rest of the 20% space would be used for supporting facilities and activities, e.g. toilet, bathroom, kitchen, registration area, circulation, etc. In this way, available area of open spaces was calculated and available floor space of the public buildings (educational/ religious institution and public building used for community facility) were found. It was assumed that a person needs 1.8 m^2 of space in temporary shelter (Sphere Project, 2011; Xu, Okada, Hatayama, & He, 2006). Accordingly, number of persons that can be accommodated in the selected temporary shelters were calculated for safe and unsafe facilities separately.

c) Demand Supply Comparison

After the calculation, the demand for temporary shelter and supply of safe temporary shelter have been compared to understand surplus or deficit of temporary shelter in the study area. Additionally, potential of the institutional buildings (now unsafe) which can be used as temporary shelter if retrofitted was also analyzed to cover the deficit (if occur) or to support surrounding areas.

d) Finalization of Selection and Estimation through Workshop

In future a workshop will be arranged in the study area where the demand, safe temporary shelters, demand supply comparison, and the potential to allocate homeless people in institutional buildings (now unsafe) which can be used as temporary shelter if retrofitted will be presented to the local people. Here the local participants will assess the potentials of these places of temporary shelters. Based on their feedback, final selection and estimation of the temporary shelters will be done.

e) Estimation of Supporting Facilities in Selected Temporary Shelters

Temporary shelters need to meet the need of the people staying in the shelters after an earthquake. Therefore, there is need for toilet, water, and first aid treatment facility etc. After final selection of the temporary shelters, the need for supporting facilities will also be estimated considering their capacity (Sphere Project, 2011).

Table 3.6: Assumptions for estimating facilities in temporary shelters

Facility/ Amenity	Standard
Toilet	1 per 50 persons
Water	15 liters per person per day
People requiring first aid treatment	50% of people in temporary shelter
Volunteer with first aid treatment training	1 per 72 injured people
First aid box	1 per 10 injured people

Source: Sphere Project, 2011

3.9.2 Emergency Health Facility Planning

The collapse of structural buildings due to earthquake may result in death and severe injury to the people of the study area. Emergency health facilities will be required to minimize the sufferings of the injured people after an earthquake. The steps for emergency health facility planning in the study area are discussed in the following sections.

a) Need Assessment (Demand Calculation for Emergency Health Facility)

After an earthquake, people may be injured at different severity level requiring different level of medical facility accordingly. Table 3.7 shows different severity level of injury after an earthquake with corresponding description of the injury level and treatment requirement. From the Table it can be observed that people with severity level two and three would require emergency health facility. Level one injury can be treated by first aid and severity level four injury would require specialized facilities in regional health facility. Therefore, the target group for the emergency health facilities in the study area would be decided based on injury level. That means people with severe injury would be given priority for emergency health facility.

Table 3.7: Different severity level of injury after an earthquake

Severity level of injury	**Description of the injury**	**Treatment requirement**
Severity 1	Some examples are a sprain, a severe cut requiring stitches, a minor burn (first degree or second degree on a small part of the body), or a bump on the head without loss of consciousness.	First aid treatment at disaster shelters: Require basic medical aid that could be administered by paraprofessionals or persons with first aid training. These types of injuries would require bandages or observation.
Severity 2	Some examples are third degree burns or second degree burns over large parts of the body, a bump on the head that causes loss of consciousness, fractured bone, dehydration, or exposure.	Emergency health facility: Require a greater degree of medical care and use of medical technology such as x-rays or surgery, but not expected to progress to a life-threatening status.
Severity 3	Some examples are: uncontrolled bleeding, punctured organ, other internal injuries, spinal column injuries, or crush syndrome.	Emergency health facility: Injuries that pose an immediate life-threatening condition if not treated adequately and expeditiously.
Severity 4	Instantaneously killed or mortally injured	Regional health facility.

Source: Adapted from FEMA (2012)

In this research, it has been assumed that the people occupying in vulnerable buildings with probability of extensive or complete structural damage after an earthquake would be injured in the study area requiring emergency health facility. Considering the assumption, firstly the vulnerable buildings in the study area with probability of extensive or complete structural damage were estimated accordingly. From section

"3.5.3 Primary Data Collection for Preliminary Vulnerability Assessment of Buildings: Rapid Visual Screening (RVS) Method" it can be observed that sample number of buildings in the study area have been assessed for building vulnerability. Now demand estimation based on scenario of the sample buildings would underestimate the demand scenario. Again, the sample size represents the population at 95% confidence level and 5% confidence interval. Therefore, the scenario of extensive or complete structural damage of sample buildings were translated into the total buildings in the study area proportionally with respect to structure type and number of storey of the buildings. Now, structure type of all the buildings were also missing in the database. Therefore, proportion of structure types found from sample buildings were considered representative of total buildings. In this way, number of vulnerable buildings with probability of extensive or complete structural damage after an earthquake in the study area were estimated with respect to structure type and number of storey.

After the identification of the vulnerable buildings, it was necessary to estimate the number of people occupying in these buildings. The data on building wise occupancy were unavailable. So, occupancy per floor was estimated in this research. While doing so population in Ward 8 in 2020 was calculated from the population of 2011 using the annual growth rate of Rangamati District. Then total number of floors in the study area was estimated from all buildings and their corresponding number of storey. From total population and total number of floors in the buildings in the study area, gross number of people occupying per floor was estimated. Using this occupancy per floor, number of people occupying in the identified vulnerable buildings (with respect to structure type) with probability of extensive or complete structural damage were estimated accordingly in the study area. Among them, people requiring disaster shelters were estimated based on the assumptions as per HAZUS technical manual (FEMA, 2012). Here only the surveyed buildings have been considered for injury estimation. The assumptions considered in this research for calculation of injury with respect to severity level is shown in Table 2. Equation 1, 2, 3 and 4 show the formulas for injury estimation in the study area at different severity level.

Table 3.8: Assumption for calculation of injury

Probable damage state of vulnerable buildings	Severity level of injury (% of people residing in the building)			
	Severity 1	**Severity 2**	**Severity 3**	**Severity 4**
Extensive Structural Damage (all structure type except URM)	1	0.1	0.001	0.001
Extensive Structural Damage (URM structure type)	2	0.2	0.002	0.002
Complete Structural Damage With Collapse (all structure type)	40	20	5	10

Source: Adapted from FEMA (2012)

$I_{ie} = \sum B_e \times n \times p \times F_{ie}$ ……………………………………………(Equation 4)

Here,

I_{ie} = Number of injured people at severity level 'i' occupying in vulnerable buildings with probability of extensive structural damage (all structure type except URM)

B_e = Number of vulnerable buildings with probability of extensive structural damage (all structure type except URM)

n = Number of floors in the corresponding buildings

p = Occupancy per floor

F_{ie} = Percentage of people injured at severity level 'i' in vulnerable buildings with probability of extensive structural damage (all structure type except URM)

$I_{ieu} = \sum B_{eu} \times n \times p \times F_{ieu}$ ……………………………………………(Equation 5)

Here,

I_{ieu} = Number of injured people at severity level 'i' occupying in vulnerable buildings with probability of extensive structural damage (URM structure type)

B_{eu} = Number of vulnerable buildings with probability of extensive structural damage (URM structure type)

n = Number of floors in the corresponding buildings

p = Occupancy per floor

F_{ieu} = Percentage of people injured at severity level 'i' in vulnerable buildings with probability of extensive structural damage (URM structure type)

$I_{ic} = \sum B_{c} \times n \times p \times F_{ic}$ ………………………………………………(Equation 6)

Here,

I_{ic} = Number of injured people at severity level 'i' occupying in vulnerable buildings with probability of complete structural damage (all structure type)

B_{c} = Number of vulnerable buildings with probability of complete structural damage (all structure type)

n = Number of floors in the corresponding buildings

p = Occupancy per floor

F_{ic} = Percentage of people injured at severity level 'i' in vulnerable buildings with probability of complete structural damage (all structure type)

$I_{i} = I_{ie} + I_{ieu} + I_{ic}$ ……………………………………………………(Equation 7)

Here,

I_{i} = Total number of injured people at severity level 'i'

I_{ie} = Number of injured people at severity level 'i' occupying in vulnerable buildings with probability of extensive structural damage (all structure type except URM)

I_{ieu} = Number of injured people at severity level 'i' occupying in vulnerable buildings with probability of extensive structural damage (URM structure type)

I_{ic} = Number of injured people at severity level 'i' occupying in vulnerable buildings with probability of complete structural damage (all structure type)

b) Estimating Availability of Space for Providing Medical Support:

For emergency treatment after an earthquake, the existing hospitals, clinics, and diagnostic centers in the study area were identified. Here mixed use buildings have also been selected considering the urgent demand at the time of emergency. The health facilities should be structurally safe. Therefore, the facilities located in the structurally safe building (with RVS score equal to or greater than 1.2) were identified as a possible emergency health facility. The unsafe buildings were also considered as potential to provide health facility after an earthquake, if retrofitted accordingly. Thus, estimation of space in safe and unsafe structures were done separately. It is ideal to consider number of beds to estimate the capacity of the health facilities to treat people. But at the time of emergency after an earthquake, number of injured people would be high and therefore these facilities will have to have additional capacity to treat the injured people. Therefore, for estimation of capacity of the selected emergency health facilities, total floor area in health facility buildings and the health facility floor areas in mixed use buildings were considered for emergency health facility. For the cases of mixed use buildings which consists of residential and health use, only one floor was considered for health facility. For the cases of mixed use buildings which consist of commercial and health use, only one floor was counted for commercial purpose and the rest for emergency health facility purposes. After calculation of floor areas in the health facilities, it was considered that the whole space would not be usable for functional for shelter purpose. Thus, functional spaces for treatment purpose in the selected emergency health facilities were calculated. For this purpose, it was assumed that 80% of the available space would be used as health facility. The rest of the 20% space would be used for supporting facilities and activities, e.g. toilet, bathroom, kitchen, registration area, circulation, etc. Again, as these facilities are continuous functional, therefore, some space would be occupied at the time of emergency. Here it was assumed that about 50% of the usable space (within above mentioned 80% floor area) would be occupied by patients who were admitted to the facility before the earthquake. It was assumed that a person would need 2m2 space in an emergency health facility (Sphere Project, 2011 & Xu, Okada, Hatayama, & He, 2006). Accordingly, numbers of persons that can be treated in the selected emergency health facilities were calculated for safe and unsafe facilities separately.

In this preparation of contingency plan, hospitals, clinics, and diagnostic centers in the study area have been considered for emergency health facilities and pharmacies have been considered for only first aid treatment.

c) Estimation of Support Facilities to run Medical Facilities:

As all the identified health facilities are now operating as health facility, so it is logical to assume that they have the necessary support infrastructure. However, in the aftermath of an earthquake these facilities have to support more than their designed population. So, this estimation also has to be done according to standards (Table 3.9).

Table 3.9: Assumptions for estimating facilities in health facilities

Facility	Standard
No. of Toilet	1 per 20 persons
Amount of Water	50 liters per person per day
No. of Doctor	1 for 20 patient
No. of Nurses	4 nurses with each doctor

Source: Sphere Project, 2011

3.9.3 Evacuation Route Planning

Evacuation route is an escape designated to a facility (temporary shelter, hospital etc.) in an emergency situation, such as a fire or earthquake (CollinsDictionary.com, 2018). Evacuation route planning is a complex process consisting of several consecutive phases. After the detection of potential disaster, it is necessary to evaluate the potential threat for specific areas and then issue an evacuation order for these areas from the vulnerable area to a safe place to provide adequate protection to the residents and others. Evacuation planning is influenced by the condition of infrastructure of the affected area to ensure the accessibility to the safer place. Following steps have been followed to determine evacuation route:

(a) Identifying Vulnerable Building:

Buildings which have an RVS score less than 1.2 have been considered as vulnerable. It is assumed that debris from the collapsed building would partially or fully block the road considering different contexts.

(b) Determining Blockage in the Road:

The height of each storey of the building was considered 10 feet.

- ***No block condition:***
    - Vulnerable URM building below four stories: These buildings will not collapse due to an earthquake. If does, then it would collapse on the site. So these buildings will not block the adjoining roads (Figure 3.9a).
    - Vulnerable RCC building below four stories: These buildings will not collapse due to an earthquake. Hence there is no chance of any road blockage in front of those buildings (Figure 3.9b).
- ***Partial block condition:***
    - Vulnerable URM building four storied or more: If the building height is at least one feet less than the width of front road, then it has been considered that the road will be partially blocked. Because there will be at least one feet space for movement of people. That means the adjacent road will not be fully blocked (Figure 3.10a).
    - Vulnerable RCC building four storied or more: First condition is that, if the building height is at least one feet less than the width of front road, then it has been considered that the road will be partially blocked. Because there will be at least one feet space for movement of people. That means the adjacent road will not be fully blocked (Figure 3.10b). Second condition is that if the building

height is greater than the width of front road, and safe building with more than one storey on the opposite side of the road, then the building will have stuck on the opposite building leaving some space for movement of people underneath (Figure 3.10c)

- ***Full block condition:***
    - Vulnerable URM building four storied or more: If the building height is greater than or equal to the width of front road, then it will fully block the road in front of it (Figure 3.11a).
    - Vulnerable RCC building four storied or more: If the building height is greater than or equal to the width of front road, and there is either no building or semi pucca or katcha or one storied safe pucca or one storied or multi storied vulnerable building on the opposite side of the road, then it will fully block the road in front of it (Figure 3.11b).

(a) URM buildings (Bhuj Earthquake 2001, India (Dinodia Photos RM, 2001))

(b) RCC buildings (Bhuj Earthquakes 2001, India (Datta, 2001))

Figure 3.9: No block conditions

(a) URM buildings (Bhuj Earthquakes 2001, India (Singhania, 2016))

(b) RCC building first condition (Great Hanshin Earthquake 1995, Japan (Yamanaka, 1995))

(c) RCC building second condition (Bhuj Earthquakes 2001, India (Langenbach, 2001))

Figure 3.10: Partial block conditions

(a) URM buildings (Nepal earthquake, 2015 (Masood, 2015))

(b) RCC buildings (Taiwan earthquake, 2016 (NDTV, 2016))

Figure 3.11: Full block conditions

(c) Accessibility of the Open Roads:

Once the blocked roads are identified the rest of the open roads will be considered based on their accessibility considering road width. The routes have been classified in seven groups:

- Routes, where the pedestrian and one-way bicycle can move i.e. road width, is less than 4 feet
- Routes, where one-way non-motorized traffic (rickshaw or van), one-way motorcycle and two-way bicycle can move i.e. road width, is 4 to 8 feet
- Routes, where two-way non-motorized traffic (rickshaw or van), two-way motorcycle and bicycle can move i.e. road width, is 8 to 12 feet

- Routes which can be used as single carriageway i.e. road width, is 12 to 25 feet.
- Routes which can be used as two-lane carriageway i.e. road width, is 25 to 40 feet.
- Routes which can be used as secondary road i.e. road width, is 40 to 60 feet.
- Routes which can be used as main/primary road i.e. road width, is greater than 60 feet. (Government of Bangladesh, 2004; Roads & Highways Department, 2004)

(d) Identifying Evacuation Route:

The partial or full blockages on the roads have been shown in point feature, using ArcGIS. Based on road blockage and accessibility, the evacuation route map will be prepared in ArcGIS. This route will be usable for the evacuees to move to the temporary shelters, to take the injured people to the health facilities and to connect the temporary shelters and the health facilities with the Ward Co-ordination Center.

3.9.4 Identification of space for Ward Co-ordination Center

Ward Co-ordination Center is required during disaster in order to ensure proper mobilization and management of personnel and necessary equipment, and supplies immediate after an earthquake. In identifying Ward Co-ordination Center following criteria will be considered

- the facility should be in a government building,
- should be structurally safe and
- should be centrally located and easily accessible

3.10 Finalization of the plan at Local Workshop

It should be mentioned here that the initial contingency plan would be revised once all data is processed. It is expected that before finalization of the plan, the draft plan will be shared with local community in a workshop. In the workshop, according to the feedback from the community, necessary changes regarding temporary shelter, health facility and evacuation route would be made. The Ward Co-ordination Center can also be changed on their suggestion as happened in Mymensingh (JIDPUS & DURP, 2018).

Additionally, the participants may identify some roadblocks or area, which would be inaccessible during monsoon. Based on their feedback, the evacuation route plan will be finalized and some recommendations will be developed to remove the identified road blockage. It is expected that this workshop will be participated by the Honorable Mayor of Rangamati Pourashava, officials from Rangamati Pourashava, officials from UNDP, Ward Councilor of Ward no. 8, representatives of different groups, members of civil society, earthquake volunteers and other representatives from Ward no. 9, Rangamati Pourashava.

3.11 Final Report Preparation

Once the local workshop is concluded, the final report will be prepared. The report will contain not only the result of the study with appropriate figures, maps and tables but also recommendation to reduce the vulnerability of the community.

CHAPTER 4: SITE SPECIFIC SEISMIC HAZARD ASSESSMENT

4.1 Introduction

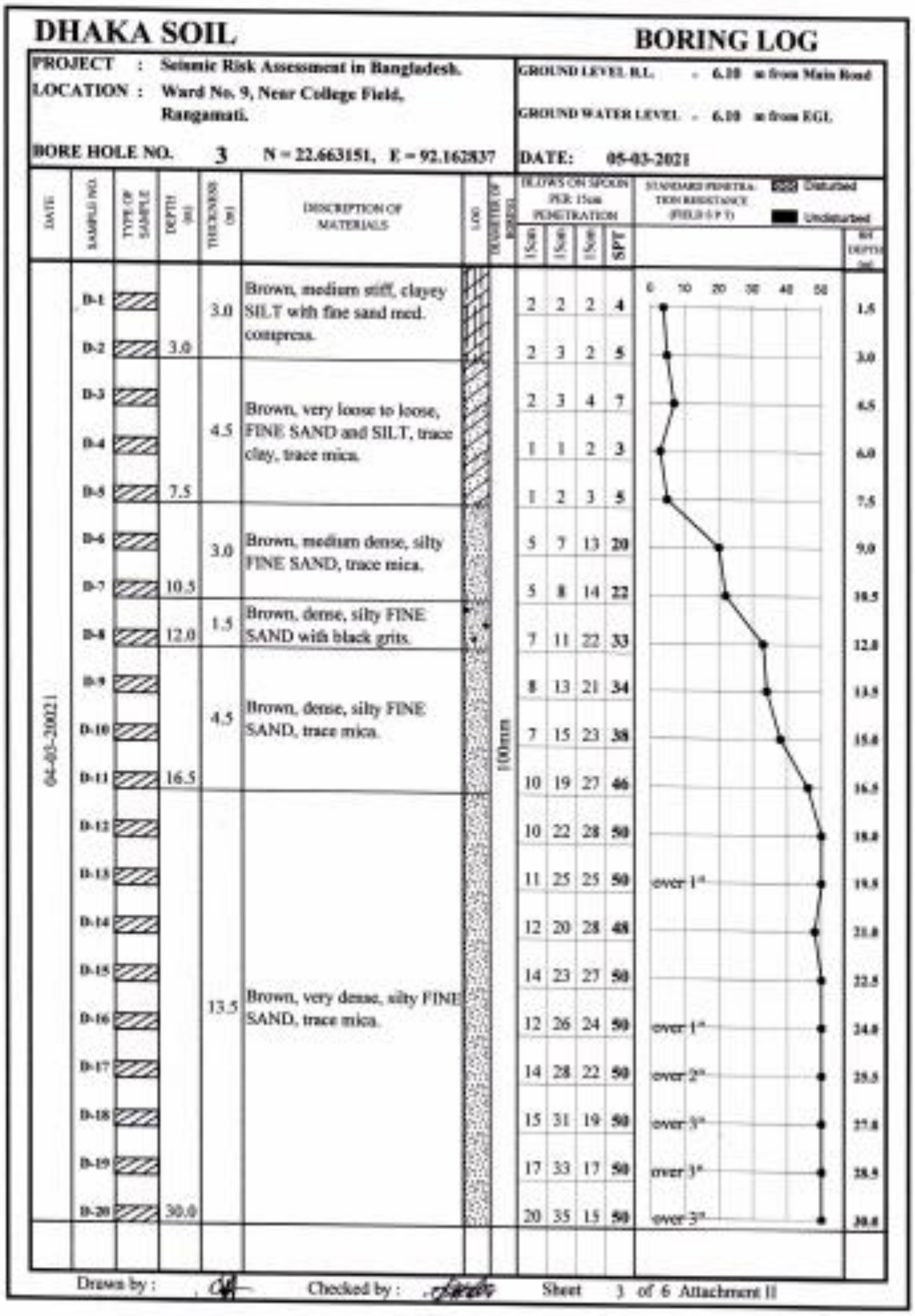
This chapter deals with the borehole location and soil profile for Ward no. 9 of Rangamati Pourashava. It also presents information regarding the microtremor test for determination of natural frequency. It will help to know the local soil condition and local seismic effect.

4.2 Borehole Data (SPT value and Description of Soil)

Figure 4.1 and Figure 4.2 represent the bore logs of the two bore holes of Ward 9 of Rangamati Pourashava. One boring (Bore Hole 1) was done near college field and another boring (Bore Hole 2) was done near a stadium. Bore hole diameter, used in these tests was 100 mm. Both disturbed and undisturbed samples were collected from the borings. 20 readings of SPT-N value at 1.5m interval up to 30 m were taken.

The soil profile of bore hole 1 in Figure 4.1 shows six different layers of soil. The N value up to 7.5m is less than 10. So, the top 7.5m have less strength. Beyond this, the N value increases up to 19.5 m, then there is a slight decrease in next 1.5m, the value increases once again. In the last layer of soil, the maximum value of N is 50 which are obtained from 22.5 to 30 meters. The detailed description of the soil types are shown in Figure 4.1.

On the other hand, the soil profile of bore hole 2 in Figure 4.2 shows four different layers of soil. It is observed that up to 9m, the N values are below 10. So, the soil up to 9m has less strength. Beyond 9.0m the N values keep increasing. The bottom most layers (24m to 30.0m) reaches an N value of 50. So, the depth of soil layer with low strength is greater in bore hole 2 than compared to bore hole 1.



DHAKA SOIL **BORING LOG**

PROJECT : Seismic Risk Assessment in Bangladesh.
LOCATION : Ward No. 9, Near College Field, Rangamati.
BORE HOLE NO. 3 N = 22.663151, E = 92.162837

GROUND LEVEL R.L. - 6.10 m from Main Road
GROUND WATER LEVEL - 6.10 m from EGL
DATE: 05-03-2021

DATE	SAMPLE NO.	DEPTH (m)	THICKNESS (m)	DESCRIPTION OF MATERIALS	DIAMETER OF BORING	15cm	15cm	15cm	SPT	BOT DEPTH (m)
04-03-20021	D-1		3.0	Brown, medium stiff, clayey SILT with fine sand med. compress.	100mm	2	2	2	4	1.5
	D-2	3.0				2	3	2	5	3.0
	D-3		4.5	Brown, very loose to loose, FINE SAND and SILT, trace clay, trace mica.		2	3	4	7	4.5
	D-4					1	1	2	3	6.0
	D-5	7.5				1	2	3	5	7.5
	D-6		3.0	Brown, medium dense, silty FINE SAND, trace mica.		5	7	13	20	9.0
	D-7	10.5				5	8	14	22	10.5
	D-8	12.0	1.5	Brown, dense, silty FINE SAND with black grits.		7	11	22	33	12.0
	D-9		4.5	Brown, dense, silty FINE SAND, trace mica.		8	13	21	34	13.5
	D-10					7	15	23	38	15.0
	D-11	16.5				10	19	27	46	16.5
	D-12		13.5	Brown, very dense, silty FINE SAND, trace mica.		10	22	28	50	18.0
	D-13					11	25	25	50 (over 1")	19.5
	D-14					12	20	28	48	21.0
	D-15					14	23	27	50	22.5
	D-16					12	26	24	50 (over 1")	24.0
	D-17					14	28	22	50 (over 2")	25.5
	D-18					15	31	19	50 (over 3")	27.0
	D-19					17	33	17	50 (over 3")	28.5
	D-20	30.0				20	35	15	50 (over 3")	30.0

Drawn by : Checked by : Sheet 3 of 6 Attachment II

Figure 4.1: SPT data of Bore Hole 1 of Ward 8

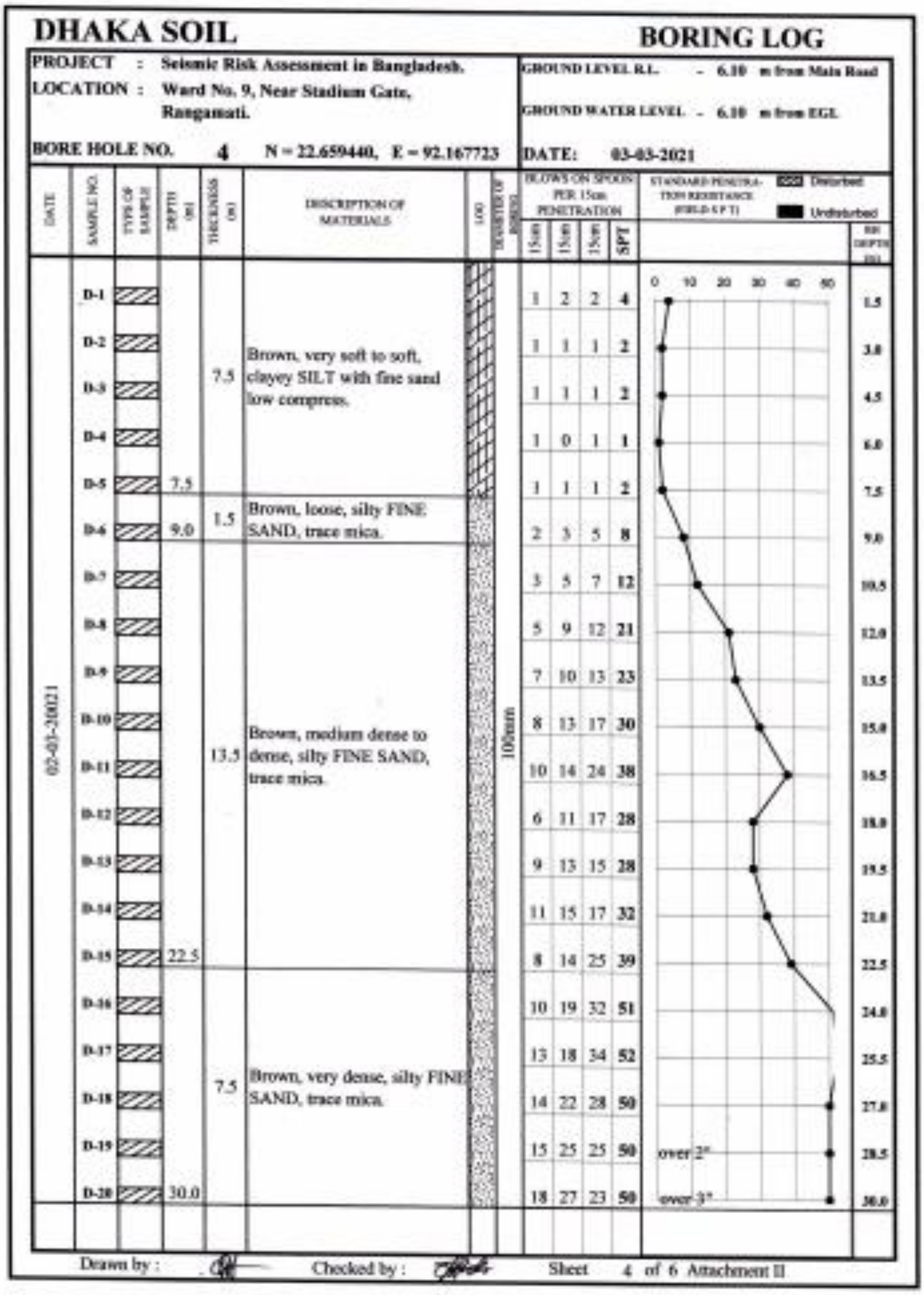


Figure 4.2: SPT data of Bore Hole 2 of Ward 8

4.3 Microtremor Test

Microtremor test was conducted at one location of ward no. 9 of Rangamati Pourashava. The methodology has been stated in article 3.5 of Chapter 3.

4.3.1 Result of Microtremor Analysis

For microtremor test, data was recorded for one hour at a sampling frequency of 100 Hz. For each sensor, the data set has been divided into 25 segments each containing 8192 data points. After segmenting, the data set the data was through a band pass filter to eliminate very high and very low frequencies. Fast Fourier Transformation (FFT) has been used to transfer time domain data of each window to frequency domain data.

By dividing the horizontal component (vibrations recorded in N-S and E-W directions) by the vertical component (vibrations recorded in Up-Down direction) we obtained the amplitude. All the graphs have been smoothened by averaging 20 data points and considering it as a single point in the graph.

Using empirical equation along with the soil profile obtained from the bore holes, the shear wave velocity of the 30 meter 1-D soil column was found to be around 148.65 m/s (Bore hole-1) and 157.73 m/s (Bore hole-2), yielding an average of 153.18 m/s. From calculation, the predominant period for the soil was obtained as 0.783 second. Hence, for the location of the microtremor test, the predominant/natural frequency of the soil, at which the amplitude of the ground motion is the maximum, is 1.28 Hz.

CHAPTER 5: BUILDING VULNERABILITY ASSESSMENT

5.1 Introduction

In this chapter, the seismic vulnerability of the buildings of Ward no. 9 of Rangamati Pourashava has been discussed based on Rapid Visual Screening of 77 buildings.

5.2 Preliminary Assessment using Rapid Visual Screening

The seismic vulnerability assessment of structures in the selected area has been done by RVS (Rapid Visual Screening) method formulated in FEMA P-154. In this method, the focus was on earthquake issues such as identifying building type, plot size and shape, clear distances from surrounding structures, road width, and basic information of the building: year of construction, number of storey, overhang, vertical irregularity, plan irregularity etc. Digital photographs of each building from at least two directions were taken.

5.3 Results and Discussion of Preliminary Vulnerability Assessment

In this section, results of the analysis are presented focusing on the main concerning point of the structure which may turn out to be vulnerable during earthquakes.

Ward no. 9 of Rangamati Pourashava has been divided into 10 clusters. This ward falls within moderately high seismicity zone according to FEMA. Four different types of buildings were obtained during the rapid visual screening of the selected buildings in Rangamati Pourashava. These, according to classification of FEMA are Wood Light Frame (W1), Concrete Shear Wall Building (C2), Concrete Frame with Masonry Infill Walls (C3) and Unreinforced Masonry building (URM). The maximum achievable score for these four types of buildings are 4.1, 2.1 1.4 and 1.2 respectively (as per FEMA requirements). However, as we consider the irregularities and soil class (D) the scores decline. So, an URM type building cannot receive a score greater than 1.2 in any circumstances. If a cut off score greater than 1.2 is set, it will not represent the true state of vulnerable buildings. Thus, a cutoff score of 1.2 has been selected. It has been observed that the final score of 51% of the total surveyed buildings in ward 9 were below cutoff (1.2) and thus these are vulnerable. Table 5.1 presents the percentage of vulnerable buildings in each cluster.

Table 5.1: Percentage of vulnerable buildings in different clusters

Cluster	Number of Building Surveyed	Number of Vulnerable Buildings	Percentage of Vulnerable Buildings
1	19	4	21%
2	15	12	80%
3	16	14	88%
5	3	2	67%
6	2	1	50%
7	7	3	43%
8	4	1	25%
9	9	3	33%
10	2	0	0%

Figure 5.1 represents relations between number of buildings and RVS score of Ward 9. This figure indicates that 21% of the buildings has a score less than or equal 0.3, 10% of the buildings has a score in between 0.4 to 0.6, 21% of the buildings score in between 0.7 to 0.9, and finally 48% building has a score greater than 1.5. Thus, 49% buildings can be marked as safe during an earthquake.

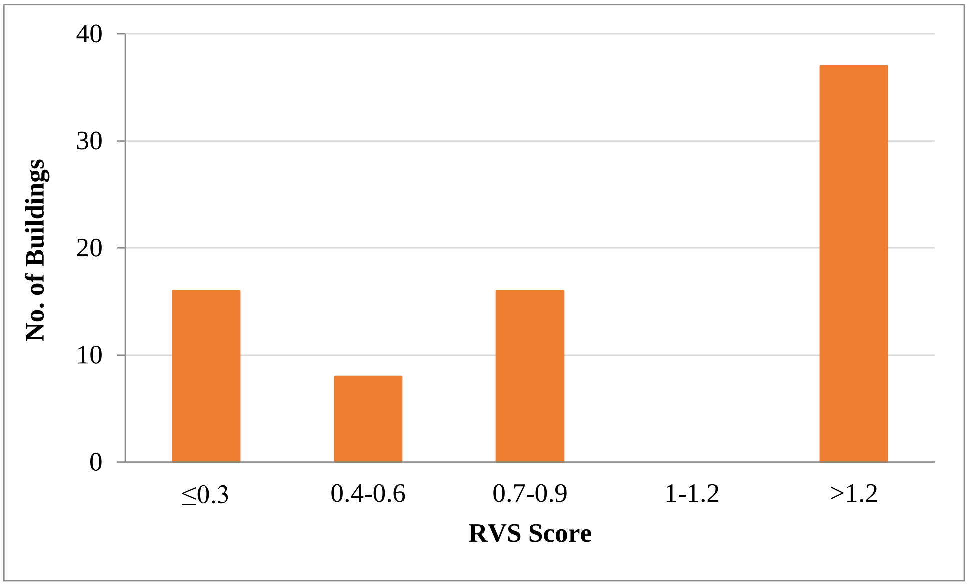


Figure 5.1: Relations between number of buildings and RVS score of ward no 9

Figure 5.2 shows the number of buildings against total number of stories. It was observed that 3 story buildings (including above and below grade) are dominating in this ward and it is 34% of the total sample size. 4 story and 2 story buildings comprise 26% and 18% of the total surveyed buildings, respectively. 13% of the buildings are 1 story 8% is 5 story. Only 1% buildings are above 5 story.

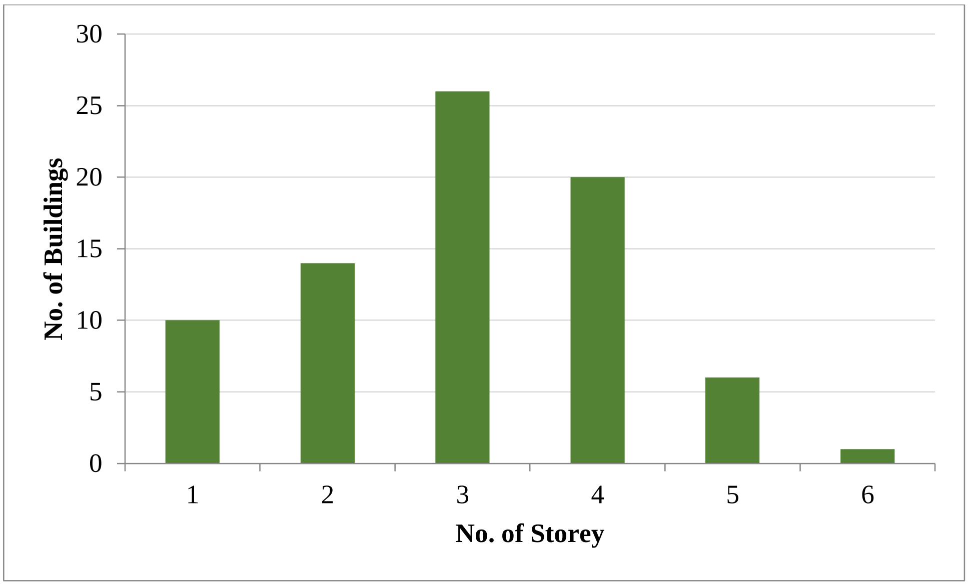


Figure 5.2: Relations between the number of buildings and total no. of storey of Ward 9

Among all the surveyed buildings, 30% had stories below grade. Figure 5.3 shows that, 23% of such buildings have 1 story below grade. 6% of them have 2 stories and 1% of them have 3 stories below grade.

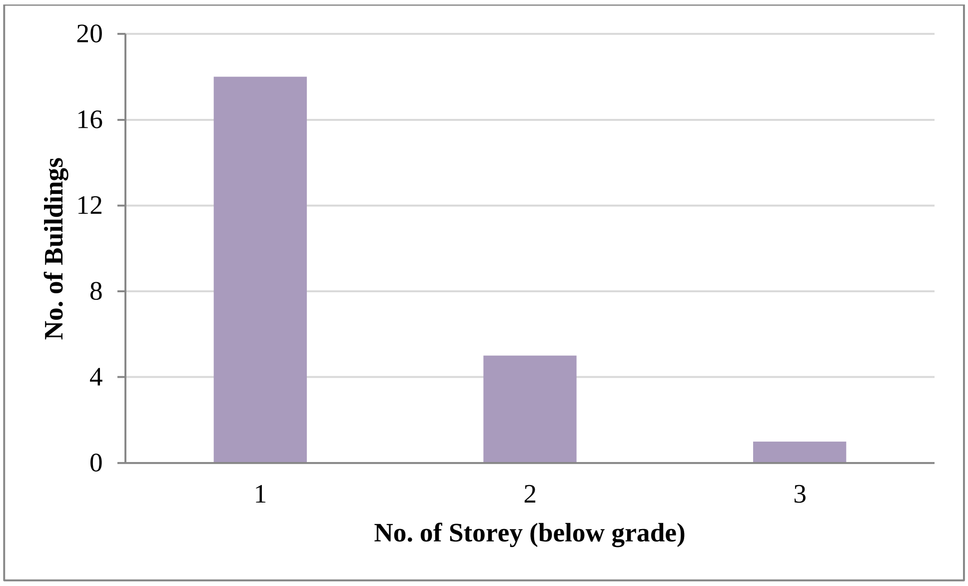


Figure 5.3: Relations between the number of buildings and no. of storey of Ward 9 (below grade)

Figure 5.4 represents relation between number of buildings and severe vertical irregularity which include any or a combination of the following: short column, soft story/weak story and out of plane setback. It has been observed that 31% of the buildings that were surveyed have severe vertical irregularity.

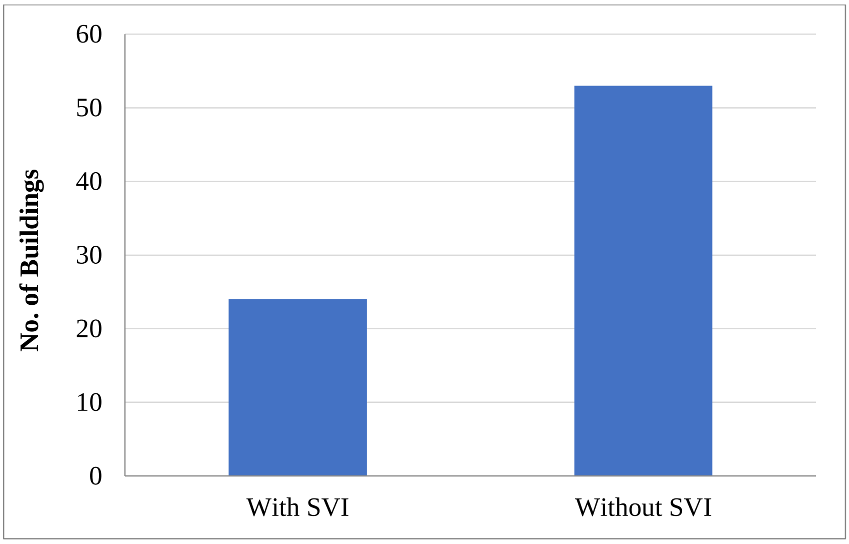


Figure 5.4: Relations between number of buildings and severe vertical irregularity

Figure 5.5 represents relation between number of buildings and moderate vertical irregularity (e.g. in plane setback, sloping site, split level). It is found that 34% of the buildings have moderate vertical irregularity.

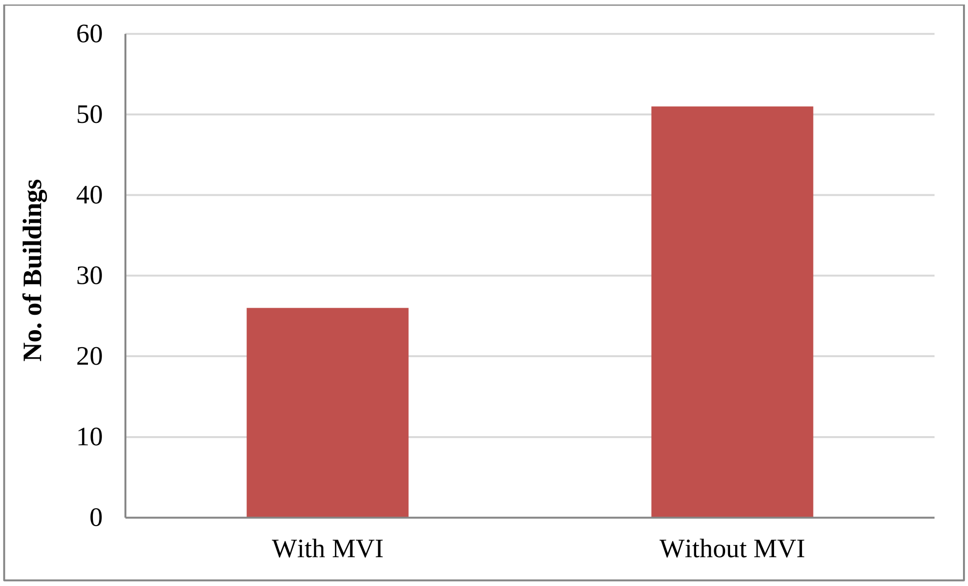


Figure 5.5: Relations between number of buildings and moderate vertical irregularity

Figure 5.6 represents relation between number of buildings and plan irregularity (e.g. torsional irregularity, non-parallel system, reentrant corner, diaphragm opening, out of plane offset). 10% of the buildings have one or more forms of plan irregularity.

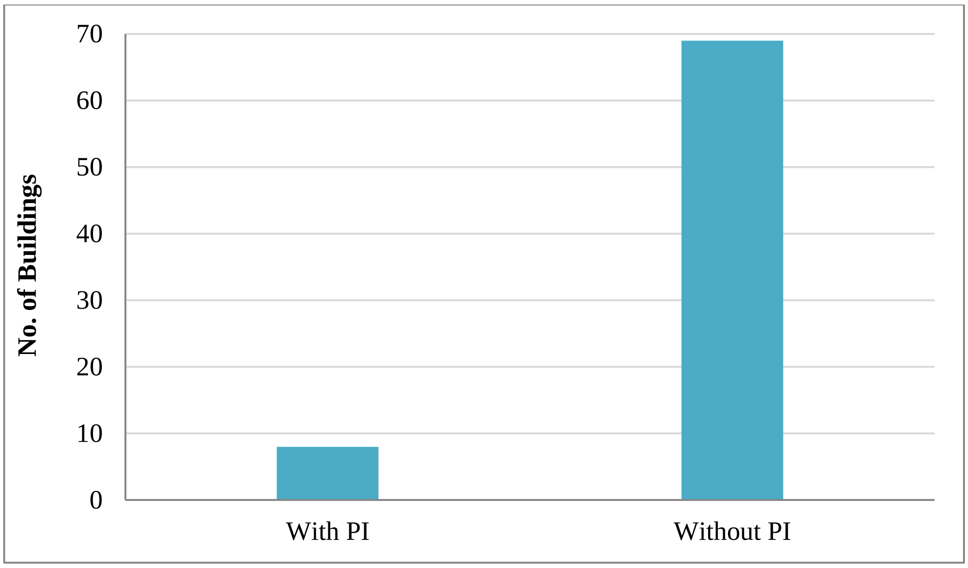


Figure 5.6: Relations between number of buildings and plane irregularity

CHAPTER 6: CONTINGENCY PLAN FOR EARTHQUAKE IN THE STUDY AREA

6.1 Introduction

In this chapter, the preliminary earthquake contingency plan prepared to reduce the seismic vulnerability of Ward No. 9 of Rangamati Pourashava has been discussed. The aspects which were intended to consider are:

- Temporary shelter: A place for peoples' temporary displacement caused by a disaster (Xu, Okada, Hatayama, & He, 2006; World Bank Institution, 2012).
- Emergency health facility: Formal health services (hospital, clinic etc.) to treat the moderate and severely injured people after an earthquake (CDMP, 2009).
- Evacuation route: Safe routes in an area for immediate transfer of victims to safer places and shelters, take the injured to health facilities and to transfer relief to the temporary shelters and emergency health facilities after an earthquake (Argyroudis, Pitilakis & Anastasiadis, 2005).
- Ward Co-ordination Center: Central command and control facility responsible for carrying out the principles of emergency preparedness and emergency management or disaster management functions at a strategic level during an emergency, and ensuring the continuity of operation at Ward level.

6.2 Temporary Shelter Planning

Temporary shelter planning for earthquake in the study area of Ward No. 9 of Rangamati Pourashava will be done first, and then demand for temporary shelter will be estimated. After estimation, demand and supply of temporary shelter in the study area will be compared to understand deficiency or surplus. In the case of draft report, only the existing and supply side scenario has been calculated. The findings are discussed here.

It is evident from prevailing literature that large-park, playground and open space, and religious, educational and public buildings are used as temporary shelter (Xu, Okada, Hatayama, & He, 2006; World Bank Institution, 2012). Additionally, from household questionnaire survey, it has been found that residents of this area prefer open space, playfield, government buildings, educational facilities, socio-cultural and urban service-related community facilities as temporary shelter. Thus, the open spaces and facility buildings (i.e., religious, educational institutions, socio-cultural and urban service related community facilities) have been considered to be used as temporary shelter in the study area. Figure 6.1 shows the location of possible temporary shelters in the study area including open spaces and public buildings. Among the facility buildings identified to be used for temporary shelter, some are structurally vulnerable (with RVS score less than 1.2) which cannot be utilized as temporary shelter. Figure 6.2 shows location of possible temporary shelters in the study area considering safety including the open spaces, safe public buildings, and unsafe public buildings. Table 6.1 shows the supply scenario of the possible temporary shelters in the study area including supply as a whole, capacity of safe facilities and capacity of unsafe facilities.

From Figure 6.2 and Table 6.1 it can be observed that most of the public buildings with higher capacity in the study area are unsafe. Table 6.1 also shows overall capacity; of safe facilities. 4244 people can be accommodated in the safe buildings. Besides, it indicates that capacity can be increased if unsafe facility buildings are retrofitted. If the unsafe buildings were retrofitted, they would be able to accommodate 1477 more people.

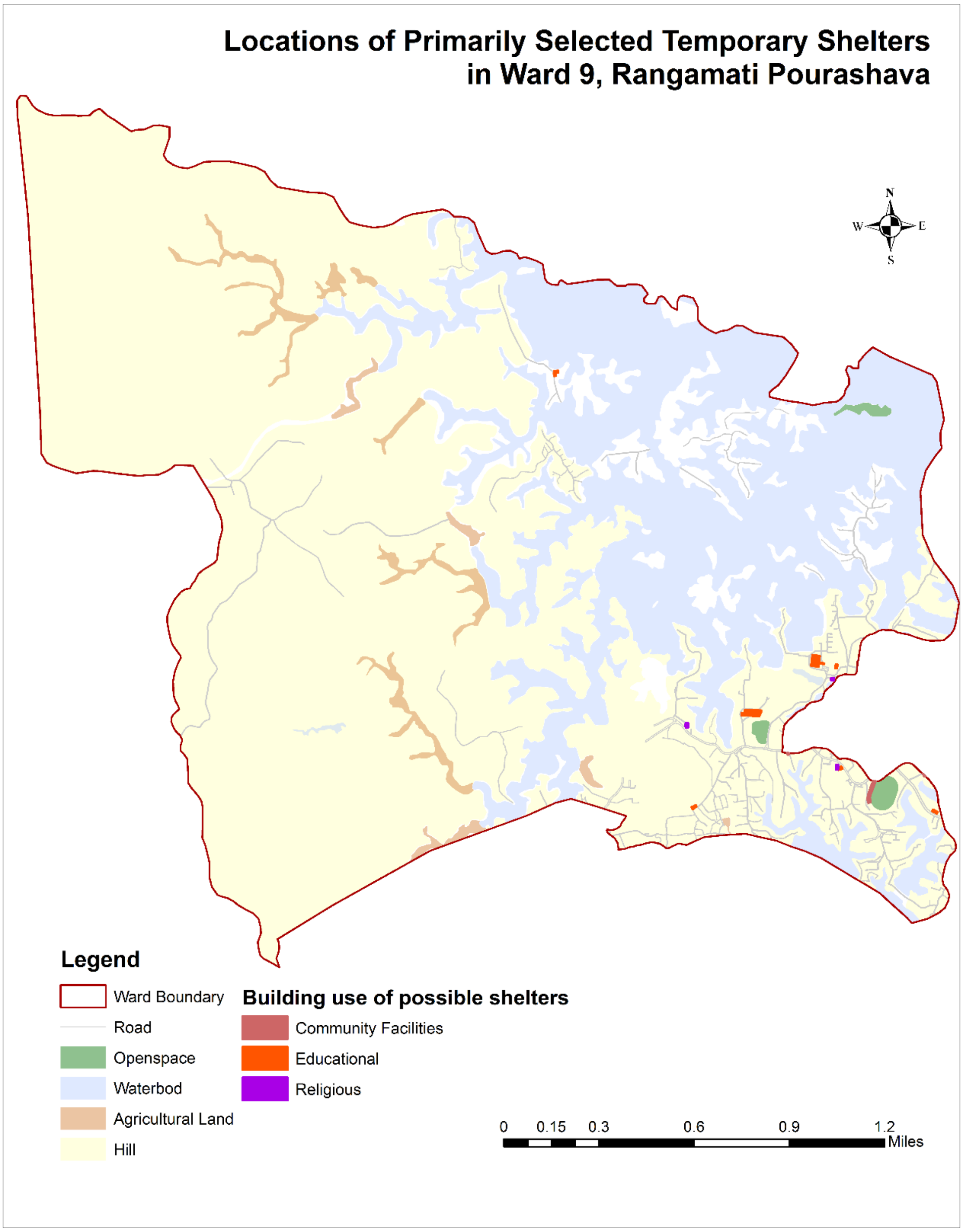


Figure 6.1: Location of possible temporary shelter in the study area

(Source: Field Survey, 2021)

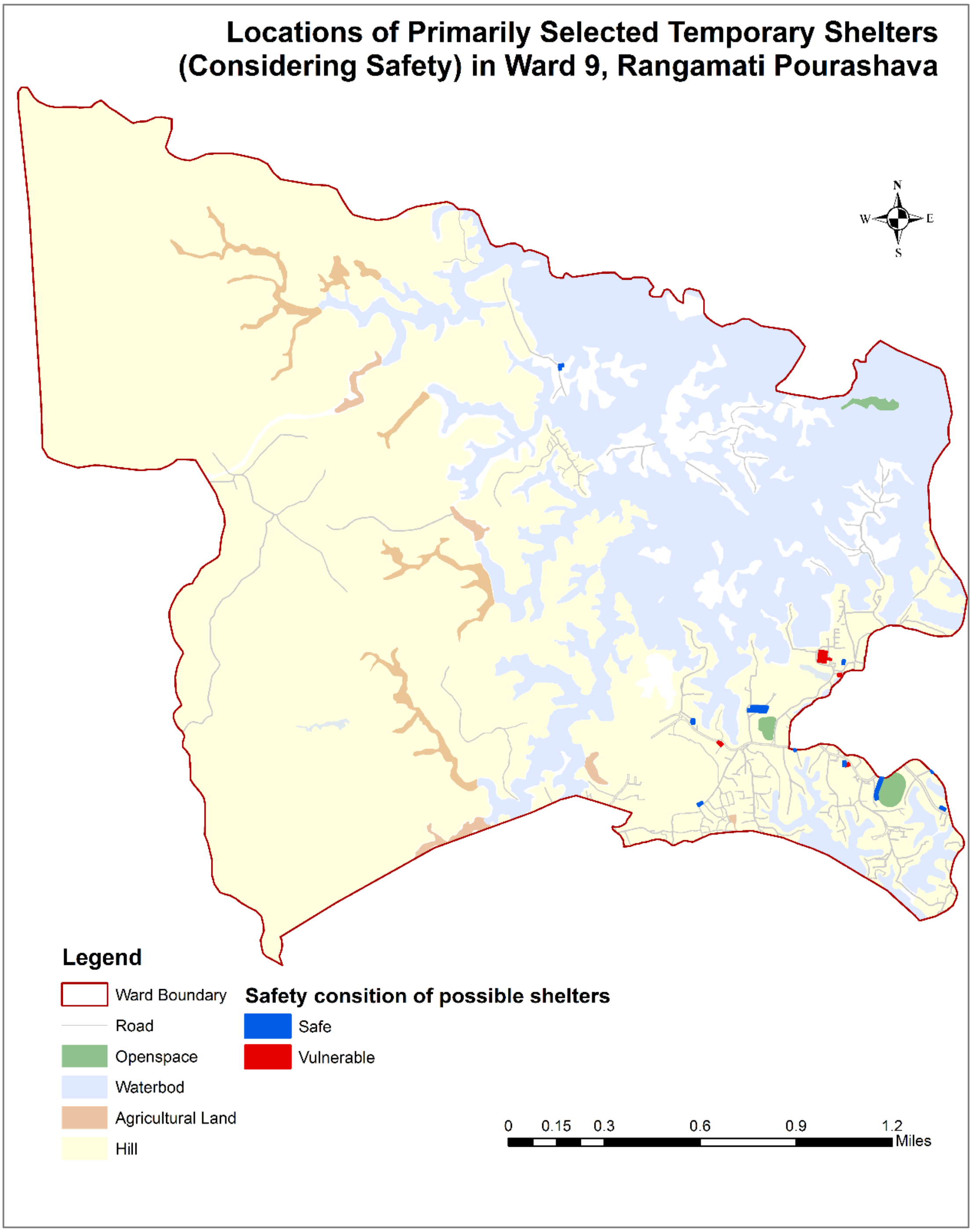


Figure 6.2: Location of possible temporary shelter in the study area considering safety

(Source: Field Survey, 2021)

Table 6.1: Supply scenario of the possible temporary shelters in the study area

Type	Total			Safe facilities			Unsafe facilities		
	Number of facilities	**Area to be used for shelter purpose (sq. m.)**	**Capacity (no. of people)***	**Number of facilities**	**Area to be used for shelter purpose (sq. m.)**	**Capacity (no. of people)***	**Number of facilities**	**Area to be used for shelter purpose (sq. m.)**	**Capacity (no. of people)***
Open space	3	30607.21554	17004						
Educational Institution	9	8468.171632	4701	6	6078.26676	3374	3	2389.904872	1327
Religious Institution	3	650.8262	360	2	379.960088	210	1	270.866112	150
Community Facility	3	1189.688016	660	3	1189.688016	660	0	0	0
Total	**18**	**40915.90138**	**22725**	**11**	**7647.914864**	**4244**	**4**	**2660.770984**	**1477**

Source: (Field Survey, 2021)

*1.8 m^2 in shelter is required per person according to Sphere Project (2011)

It needs to be noted that final selection of temporary shelters will depend on willingness of the owner of the facilities, floor plan of the structure, difficulty of converting the building to temporary shelter during need etc. In case of open space, weather condition (dry and wet seasons) is another important criteria. Moreover, due to road blockage, some of the identified temporary shelter may remain inaccessible at the event of an emergency. In future, these issues will be discussed with the stakeholders during consultation workshops to finalize the selection of temporary shelters.

6.3 Emergency Health Facility Planning

A considerable number of people would be injured in an earthquake. Considering the assumptions mentioned in Chapter 3, a possible number of injured people in the study would be calculated corresponding to different severity level in the final report. In the draft report, only present scenario and capacity has been analyzed.

Among the probably injured persons, Severity 1 can be treated in pharmacies or by primary treatment experts in a temporary shelter without being admitted to hospital. However, the people with higher-level injury (Severity 2 and Severity 3) need treatment from experts in health facilities. Injured people of Severity 4 will be instantaneously killed or mortally injured, for whom further expertise treatments will be required.

The emergency health facilities were identified as per the requirement mentioned in Chapter 3. Figure 6.3 shows locations of possible emergency health facilities in the study which includes hospital, diagnostic centre and clinics and pharmacies might be used for giving first aid treatment for injured people of severity 1. These facilities actually are not concentrated in a certain location. Capacity of the health facilities are calculated here for two scenarios. First, there has been considered only structurally safe health facility buildings. In second, structurally unsafe health facility buildings were taken into account. If only safe buildings could not meet the demand, then selected unsafe health facility buildings might be retrofitted to equalize the supply and demand. Figure 6.4 shows the emergency health facility buildings according to the structural safety of the facility building.

Considering the assumptions described in methodology chapter (Chapter 3: section 3.9.1), the capacity of each of the emergency health facilities were determined which has been shown in Table 6.2. It also shows number of emergency health facilities and their area and the number of persons they could treat considering the space requirement per person (2 square meters) for both safe and unsafe facility buildings.

It has been found from Table 6.2 that there are five hospitals and three of these are structurally safe enough to be used as emergency health facilities. If the unsafe building could be retrofitted 144 people could have been given health service at the time of emergency.

It must be remembered that final selection of emergency health facility will depend on the structural vulnerability of the facility buildings considered to be used for emergency health facility. Moreover, due to road blockage, some of the identified emergency health facility may remain inaccessible at the event of an emergency. These conditions will lead to exclusion of some possible emergency health facility. In future these issues will be discussed with the stakeholders during consultation workshops to finalize the selection of emergency health facilities.

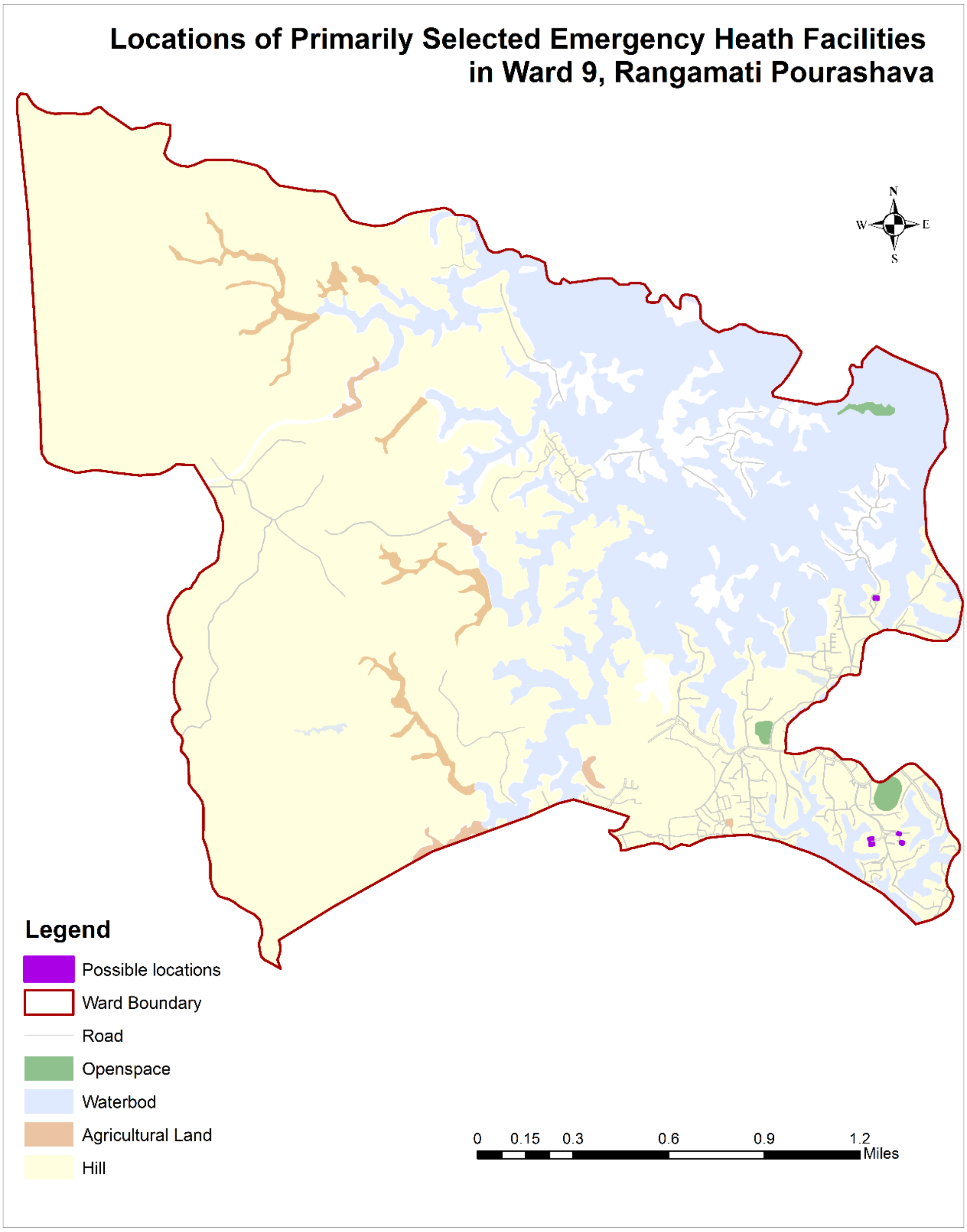


Figure 6.3: Location of possible emergency health facilities in the study area

(Source: Field Survey, 2021)

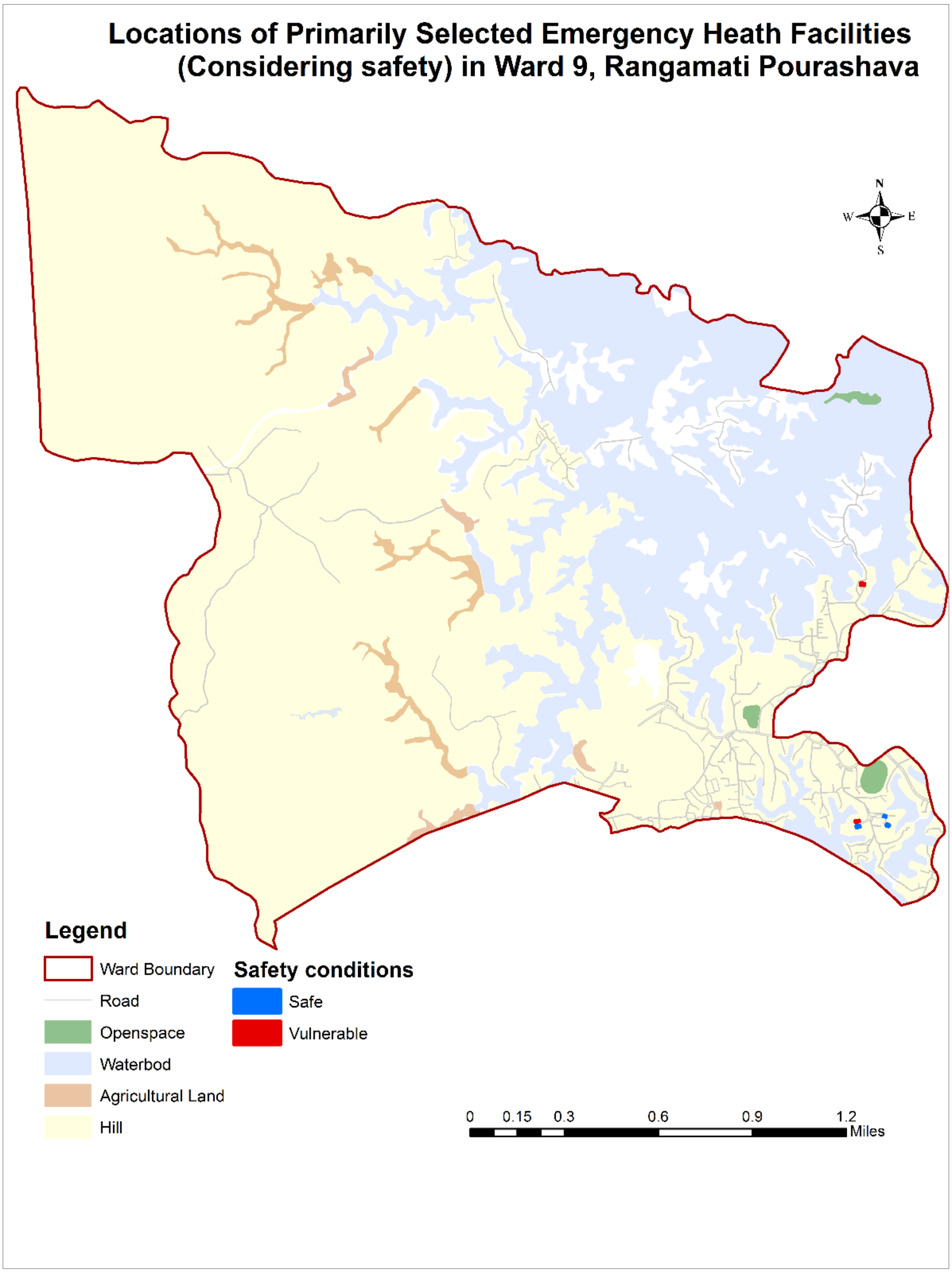


Figure 6.4: Location of possible emergency health facilities in the study area considering safety

(Source: Field Survey, 2021)

Table 6.2: Supply scenario of the possible emergency health facilities in the study area

Type	Total			Safe facilities			Unsafe facilities		
	Number of facilities	**Area to be used for shelter purpose (sq. m.)**	**Capacity (no. of people)***	**Number of facilities**	**Area to be used for shelter purpose (sq. m.)**	**Capacity (no. of people)***	**Number of facilities**	**Area to be used for shelter purpose (sq. m.)**	**Capacity (no. of people)***
Pharmacy	0	0	0	0	0	0	0	0	0
Hospital	5	498.94808	248	3	210.03	104	2	288.91808	144
Clinic	0	0	0	0	0	0	0	0	0
Diagnostic Centre	0	0	0	0	0	0	0	0	0
Total	**0**	**498.94808**	**248**	**3**	**210.03**	**104**	**2**	**288.91808**	**144**

Source: Field Survey, 2021

* 2 m^2 in shelter is required per person according to Sphere Project (2011)

6.4 Evacuation Route Plan

Most of the roads of the ward have width less than 4 feet, which is generally suitable for walking and one-way, bicycle. Four to eight feet roads are mainly seen in the northern part of the ward. These roads are accessible for one-way rickshaw, van and two-way motorcycle. Roads with higher width are very rare which means in the case of any emergency, most of the roads will not be accessible by emergency vehicles and ambulances. Besides, roads of lesser width will have higher probability of being blocked by earthquake debris (Road blockage condition will be analyzed in the final report). This information has been depicted from the accessibility map of Figure 6.5.

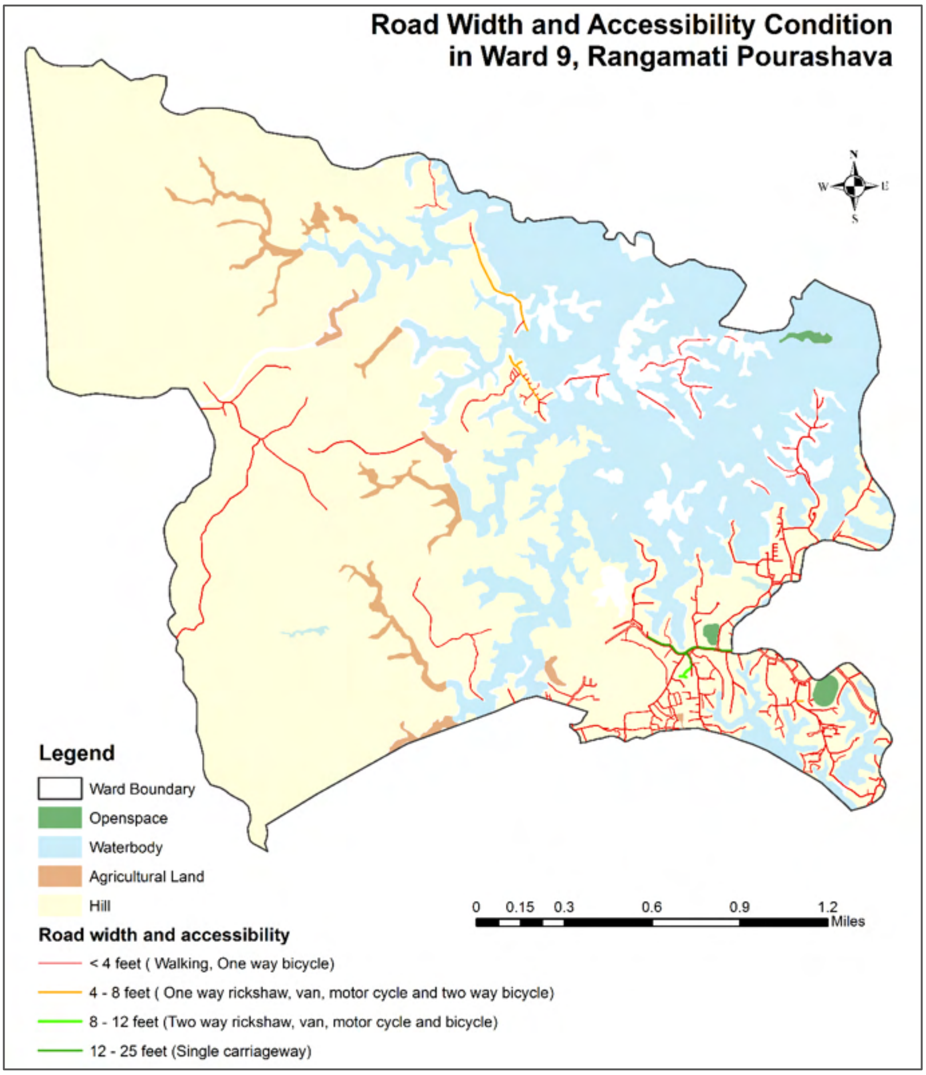


Figure 6.5: Road width and accessibility condition

(Source: Field Survey, 2021)

6.5 Ward Co-ordination Center

One of the important tasks during and after any disaster is to coordinate the different activities of management. Tasks performed by different government agencies, private organizations, volunteers, and individuals are needed to be coordinated to get the maximum benefit. In addition, WDMC needed a place to coordinate the works. For this co-ordination, Ward Co-ordination Center (WCC) is proposed to be formed in the study area. In the following sections, proposed location and institutional setup for Ward Co-ordination Center are described. Among the safe public buildings, one will be used as Ward Co-ordination Center. As mentioned earlier, the research team is still working on building vulnerability data as well as to identify the exact location of Co-ordination center the discussion with local people and stakeholders are necessary, so selection of the building to be used for WCC is under process. Moreover, final vetting of the contingency plan will be done in consultation with local people.

6.5.1 Institutional Setup and Management Activities

Figure 6.6 shows the structure of Ward Co-ordination Center Committee. Each team should contain two team leaders, but to manage the process properly each team will require more team members.

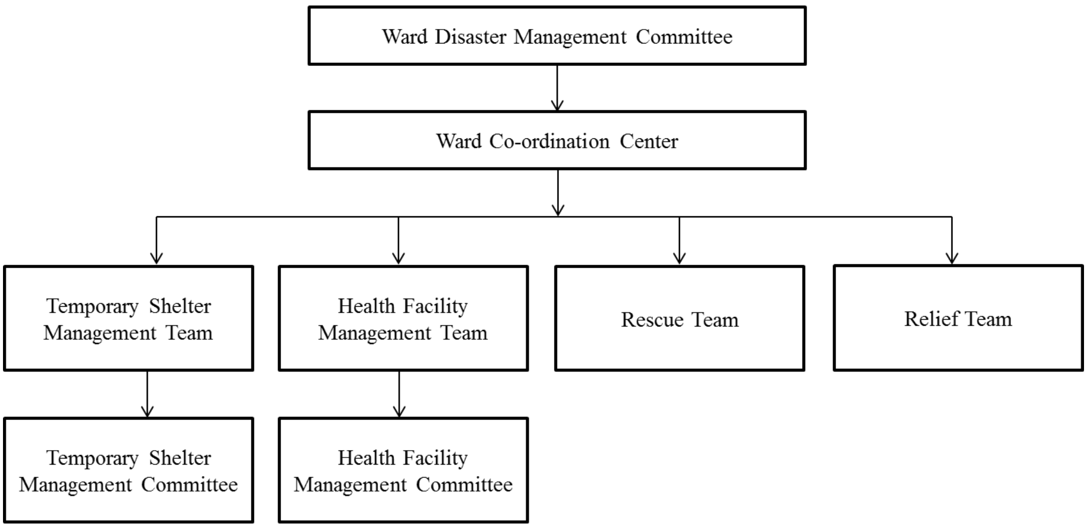


Figure 6.6: Structure of Ward Co-ordination Center Committee

All the members of the committee should meet once in three months to keep update about the responsibilities and should keep a link with the WDMC, TSMC, and EHFMC. The committee consists of the following teams.

- Temporary Shelter Management Team: Co-ordinate with all the TSMC.
- Health Facility Management Team: Co-ordinate with all the EHFMC.
- Rescue team: To take part in the rescue operation
- Relief team: To collect, manage and distribute reliefs in temporary shelters and emergency health facilities

6.5.2 Criteria for Selecting Members

All the members of the committee should be residents of the area i.e. Ward No. 9 of Rangamati Pourashava and representatives from all the clusters should be ensured. Each member should be familiar with the area. A representative from the bureaucracy of Rangamati Pourashava should also be the member of the committee. This will increase credibility and effectiveness of the committee. It is also desirable that at least one member of the owners of these private medical facilities should be co-opted in the health facility management team under this committee. The BUET team suggests there should be at least three members from the private medical facilities representing hospitals, clinics, and diagnostic centers accordingly. The members and others involved in the committee should be properly trained and their activities and responsibilities at different phases of disaster will be assigned. The assigned members should keep contact with TSMC and EHFMC, other agencies and institutions

6.5.3 Activities of Ward Co-ordination Center Committee at Different Phases of an Earthquake

To be prepared, the committees have to regularly meet and perform task before the disaster. Similarly, they have some task during and after the disaster. The following provide a tentative list of tasks the committees would perform.

a) Activities before Disaster

- A systematic program for the inspection, maintenance, and repair of buildings identified as temporary shelters and emergency health facilities at regular interval at the community level by building maintenance and rehabilitation team

- Storage of equipment and emergency supplies
- Proper dissemination of the prepared plans at the community level by victim registration and information team
- The training program at community level at a regular interval
- The arrangement of community awareness program at a regular interval such as disaster drills, emergency training, community meetings etc.
- Preparation of volunteer list at the community level and updated it at regular interval
- Distribution of activities of volunteers
- Training of volunteers based on their activities

b) Activities within 72 Hours of an Earthquake Event

- Evacuation of the people to the predefined evacuation space.
- The arrangement of necessary reliefs by the relief management team.
- Search and rescue of people by the search and rescue team.
- Disaster victim registration and segmentation of the victims according to their need for health facility and shelter requirement.
- Assessment of the suitability of the pre-identified temporary shelters and emergency health services by building maintenance and rehabilitation team. If any of the pre-identified temporary shelters and emergency health services are proved to be unsuitable, then initiative should be taken to identify alternative places to provide temporary shelter and emergency health facility.
- Assessment of the pre-identified evacuation routes (to reach the shelters and health services) to find out whether they are open or not. If required, new evacuation routes should be identified or adjustments should be done. The routes that must be opened to support health, shelter and relief operation should be given priority while clearing debris.
- The arrangement of the identified shelters with designated TSMC according to the plan for receiving people.

- Preparation of the designated emergency health facilities with designated EHFMC along with all the doctors and nurses to serve the injured people.
- The arrangement of inventory and equipment supply at Ward Co-ordination Center.

c) Activities from 72 Hours to 14 Days of an Earthquake Event

- Continue search and rescue operation
- Continue disaster victim registration
- Initiation of temporary shelter operation. The victims should be brought from the evacuation space and directly from the rescue spot to a temporary shelter. Necessary first aid should be provided to the injured people. The designated shelter management team should manage the shelter along with the help of the evacuees. Need for supplies and equipment should be estimated properly.
- Provide treatment to the injured people accordingly in the designated emergency health facilities.
- Collection of reliefs assigned to the community by the relief team from government agencies, NGOs, international organizations etc. From the center, reliefs should be distributed to the temporary shelters and the emergency health facilities according to the requirement. In the center, there should be food preparation facility. Here food for the victims should be prepared, where food preparation standards should be observed. The prepared food should be disseminated in nearby shelters and health facilities as required.
- Establishment of necessary extra emergency setups
- It will not be possible to construct permanent houses immediately. So, initiatives to construct transition shelters should be taken.

d) Activities from 14 Days to 60 Days of an Earthquake Event

- Full shelter capability should be maintained.
- The facilities of emergency health facilities should be continued.
- Relief management should be continued
- Construction of transition shelter should be initiated and completed
- Transfer of victims from temporary shelter to transition shelters or the repaired residential houses should be initiated**.**

e) Activities from 60 Days to One Year of an Earthquake Event

- The transfer of victims from temporary shelter to transition shelters or the repaired residential houses should be completed.
- The temporary shelters should be closed and the regular activities should be started.
- The construction work of permanent shelters should be started. The shelters should be allocated on land where the beneficiaries lived before the earthquake, promoting the return of displaced people to their places of origin.
- The transition of families to permanent housing should be initiated (Xu, Okada, Hatayama, & He, 2006).

CHAPTER 7: CONCLUSION

It should be bear in mind that contingency plan is neither a stand-alone document nor a static document. It should be an ongoing process integrated and coordinated with activities suggested by other documents. It is well understood that earthquake would cause damaged at regional scale. Therefore, contingency plan at regional scale should be prepared. However, the issue, which bears the highest importance, is to count the effect of an earthquake on spatial dimension at local level. Though this not the first earthquake contingency plan for Rangamati Pourashava, in the previous works, importance was given on institutional activities and less focus on local level panning. The work on this ward is not completed yet, involvement of local level planning and community participation will be ensured in the next stages. However, for successful implementation of the contingency plan, this kind of plan needed to be prepared for the other wards of the Pourashava.

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APPENDIX A

Clusters of Ward 9, Rangamati Pourashava

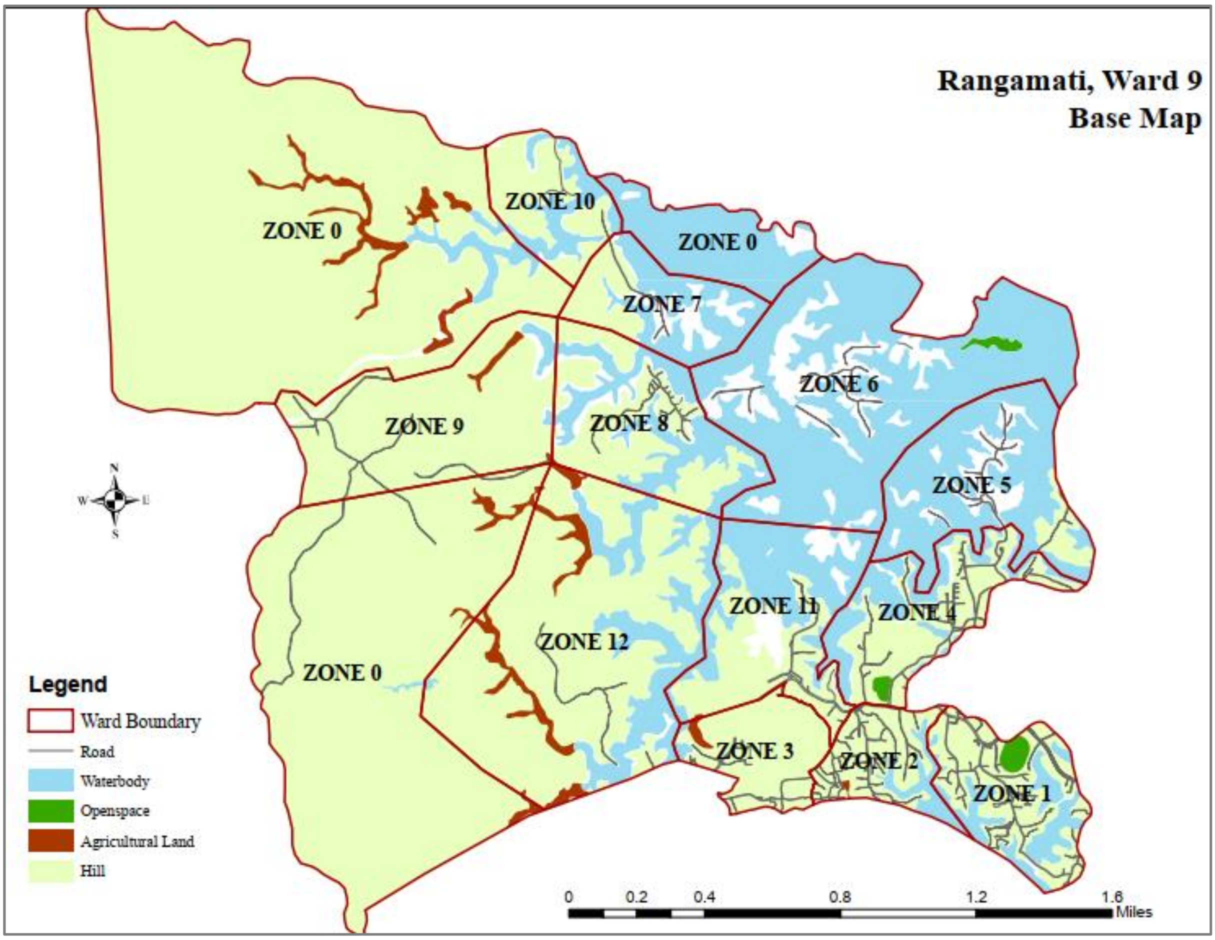

Figure: Map showing clusters of Ward 9, Rangamati Pourashava

APPENDIX B

Checklist for Data Updating

Checklist for Data Updating

1. Ward No

2. Building ID

3. Holding No

4. Type of the structure

    1. Pucca   2. Semi-pucca   3. Katcha

5. Number of storey

6. Building use

    1. Residential   2. Commercial   3. Industrial   4. Educational

    5. Community facilities   6. Health   7. Administrative   6. Religious

    7. Others

    If "Educational", please specify the type ____________________

    If "Health", please specify the type ____________________

    If "Religious", please specify the type ____________________

    If "administrative", please specify the type ____________________

    If "community facilities", please specify the type ____________________

7. Width of adjacent road (in feet)

APPENDIX C

Checklist for Rapid Visual Screening

Checklist for Rapid Visual Screening (RVS)

Ward Number

- 6
- 8
- 9

1. Building ID

---

2. Occupancy (ভবনের ব্যবহার)

Please look for the question at the supporting document

- Assembly
- Commercial
- Residential
- Industrial
- Office
- School
- Utility
- Warehouse
- Emergency Service

2.1 Total No. of Units

(if residential)

---

3. Ownership of the building (ভবনের মালিকানা)

- Public
- Private

4.1 No. of Story (ভবনে তলার সংখ্যা)

(Above Grade)

4.2 No. of Story (ভবনে তলার সংখ্যা)

(Below Grade) (if not type 0)

---

5. Floor Area (ভবনের ক্ষেত্রফল)

Approximate in ft. square

---

6. Building Type (ভবনের প্রকৃতি)

Please look for the question at supporting document

- C2 - Concrete Shear Wall Building
- C3 - Concrete Frame With Masonry Infill Walls
- URM - Unreinforced Masonry Building
- S1 - Steel Moment Resistant Frame
- S2 - Braced Steel Frame
- S3 - Light Metal Building
- S5 - Steel Frame With Unreinforced Masonry Infill Wall
- W1 - Wood Light Frame
- W1A - Multi-Storey Multi-Unit Residential (Plan Area > 3000 sq. ft)
- W2 – Wood Frame Commercial & Industrial (Plan Area > 5000 sq. ft)

7. Severe Vertical Irregularity (ভবনের তীব্র উল্লম্ব অসামঞ্জস্যতা)

Please look for the question at supporting document

- Short Column
- Soft Storey / Weak Storey
- Out of Plane Setback (if the cantilever portion is greater than 2 feet)
- None

Short Column Due To

Please look for the question at supporting document

- Irregular Wall Opening
- Deep Spandrels
- Infill Walls

Soft / Weak Storey Due To

Please look for the question at supporting document

- Large Opening
- Fewer Walls or Columns
- One of The Stories is Particularly Taller Than Others

8. Moderate Vertical Irregularity (ভবনের সহনীয় উল্লম্ব অসামঞ্জস্যতা)

Please look for the question at supporting document

- In Plane Setback

- Sloping Site
- Split Level
- None

9. Plan Irregularity (ভবনের আনুভূমিক অসামঞ্জস্যতা)

Please look for the question at supporting document

- Torsional Irregularity
- Non-Parallel System
- Reentrant Corner
- Diaphragm Opening
- Out of Plane Offset (only exterior)
- None

Specify The Type of Reentrant Corner

Please look for the question at supporting document

- L- Shaped
- T- Shaped
- U- Shaped
- Large Opening
- Weak Link Between Larger Building Plan Areas

10. Pounding Potential

Please look for the question at supporting document

- Floors are not aligning vertically
- The building is at the end of a row of three or more buildings
- Minimum gap doesn't meet
- One building is two or more stories taller than the adjacent building
- None

11. Falling Hazard

Please look for the question at supporting document

- Unsupported Water Tank
- Unsupported Parapet
- Cornices
- Heavy Cladding
- Masonry Tower
- Chimney
- Flower Pot at Roof
- None

12. Geological Hazard

Please look for the question at supporting document

- Loose Fill
- Landslide
- Organic Soil
- None

13. Significant Damage (ভবনের দৃশ্যমান ক্ষতি চিহ্নকরন)

- Visibly Sagging Beam/ Floor/ Slab
- Visibly Broken Beam/ Column
- Sloping Floor
- Large Exterior Cracks
- Visible Distress From Previous Earthquake
- Visible Fire Damage
- Visible Foundation Elements with Large Cracks
- Foundation Elements Exposed Due to Significant Erosion of Adjacent Soil
- None

Is Mortar Eroding Away?

- Yes
- No

Is There Any Exposed Rebar?

- Yes
- No

Is There Any Member Corroded?

- Yes
- No

14. Extent of Review

- Partial
- All Side

15. Interior Inspection

- Visible
- Entered
- None

Name of the Surveyor

APPENDIX D

Questionnaire for Social Survey

রাঙ্গামাটি পৌরসভার এলাকা ভিত্তিক ভূমিকম্প ঝুঁকি নিরসন এবং ব্যবস্থাপনা

প্রশ্নপত্র নম্বর ______________________ তারিখ ______________________

বিল্ডিং আইডি ______________________ ওয়ার্ড নং ______________________

প্রশ্নকারীর গ্রুপ ______________________ ক্লাস্টার নং ______________________

হোল্ডিং নং ______________________

১। উত্তরদাতার সাধারণ তথ্য

১.১ উত্তরদাতার নাম ____

১.২ আবাসিক ভবনের মালিকানা (√চিহ্ন দিন)

- সরকারী
- বেসরকারী (ব্যক্তিগত)
- বেসরকারী (যৌথ মালিকানাধীন)

১.৩ ভবনটি নির্মাণ এর সাল ______________________________________

২। পরিবারের তথ্য (আবাসিক ভবনের ক্ষেত্রে)

২.১ পরিবারে সদস্য সংখ্যা ______________________________

২.২ পরিবারের সদস্যদের বিস্তারিত বিবরন

সদস্য ক্রম	বয়স	লিংগ	শিক্ষাগত যোগ্যতা	পেশা	প্রতিবন্ধী আছে কি ? (হ্যাঁ/ না) প্রতিবন্ধকতার ধরন	ভূমিকম্প নিয়ে কোন সদস্যের প্রশিক্ষন আছে?(হ্যাঁ/ না)

১*						
২						
৩						
৪						
৫						
৬						
৭						
৮						

* উত্তরদাতা নিজে ১ম সদস্য হিসেবে বিবেচিত হবেন

বয়স	লিংগ	শিক্ষাগত যোগ্যতা	পেশা		প্রতিবন্ধকতার ধরন
১০ বছরের কম = ১ ১১ – ২০ বছর = ২ ২১ – ৩০ বছর = ৩ ৩১ – ৬০ বছর = ৪ ৬০ বছরের বেশী = ৫	পুরুষ = ১ মহিলা = ২ অন্যান্য = ৩	নিরক্ষর = ১ প্রাথমিক = ২ মাধ্যমিক = ৩ উচ্চ মাধ্যমিক = ৪ স্নাতক = ৫ স্নাতকোত্তর = ৬	সরকারি চাকুরি = ১ বেসরকারী চাকুরি = ২ ব্যবসা = ৩ শ্রমিক = ৪ ছাত্র = ৫ গৃহিণী = ৬	ডাক্তার = ৭ নার্স = ৮ শিক্ষক = ৯ অবসরপ্রাপ্ত = ১০ বেকার = ১১ অন্যান্য = ১২	মানসিক প্রতিবন্ধী = ১ শারীরিক প্রতিবন্ধী = ২ বাক প্রতিবন্ধী = ৩ দৃষ্টি প্রতিবন্ধী = ৪ অন্যান্য = ৫

২.৩ যদি কোন সদস্য ভূমিকম্প বিষয়ক প্রশিক্ষণ নিয়ে থাকেন তবে তার সাথে যোগাযোগ স্থাপনের জন্য মোবাইল নং ____________________

২.৪ উত্তরদাতার ভবনে মালিকানার তথ্য

- বাড়িওয়ালা
- ভাড়াটিয়া
- অন্যান্য

২.৫ এই পৌরসভা/ সিটি কর্পোরেশনে কত বছর যাবত আছেন ? ______________________________

২.৬ পরিবারের মোট মাসিক আয় (টাকায়)

- ২০,০০০ এর কম
- ২০,০০০ – ৩০,০০০
- ৩০,০০০- ৪০,০০০
- ৪০,০০০- ৫০,০০০
- ৫০,০০০-৭৫,০০০
- ৭৫,০০০- ১,০০,০০০
- ১,০০,০০০-১,৫০,০০০
- ১,৫০,০০০-২,০০,০০০
- ২,০০,০০০ এর বেশি

৩ উত্তরদাতার ভূমিকম্প বিষয়ক সচেতনতা, জ্ঞান এবং ধারনা

৩.১ আপনি কি ভূমিকম্প সম্পর্কে জানেন?

- হ্যাঁ
- না

৩.১.১ হ্যাঁ হলে, ভূমিকম্প বিষয়ে আপনি কি জানেন? (খোলা প্রশ্ন** এবং একাধিক উত্তর গ্রহণযোগ্য)

- এটি একটি প্রাকৃতিক দুর্যোগ
- পৃথিবীর স্থলভাগ যে প্লেট দিয়ে নির্মিত তার নড়াচড়ার কারনে এটি হয়
- ভূমিকম্পে বাড়িঘর কাপতে থাকে
- অবকাঠামোগত ক্ষতি হয়
- ভূমিকম্পে মৃত্যুঝুকি রয়েছে
- কোনটি নয়
- অন্যান্য (উল্লেখ করুন) ____

৩.২ ভূমিকম্প হলে কি করতে হয়/ করবেন? (খোলা প্রশ্ন** এবং একাধিক উত্তর গ্রহণযোগ্য)

- কাঠের কিছুর নিচে লুকাবো
- দেয়াল/শক্ত পিলারের পাশে দাড়াবো
- মাথায় বালিশ/ কম্বল ইত্যাদি রাখবো
- দ্রুত ভবন থেকে নেমে যাবো
- ছাদে চলে যাবো
- ইলেক্ট্রিসিটি/গ্যাসের লাইন বন্ধ করবো
- খুব ভয় পেয়ে যাবো
- কিছুই করবো না

- অন্যান্য (উল্লেখ করুন) ____

**খোলা প্রশ্নসমূহে উত্তরদাতাকে কোন বিকল্প (option) দেওয়া হবে না

৩.৩ আপনি কিভাবে ভূমিকম্প সম্পর্কে এসব জানতে পেরেছেন (নিম্নোক্ত বিকল্প গুলোর মধ্যে নির্বাচন করুন এবং একাধিক উত্তর গ্রহণযোগ্য)

- গণমাধ্যম (টিভি / রেডিও ইত্যাদি)
- সংবাদপত্র/ লিফলেট
- স্কুল কলেজের বইপত্র
- স্কুল-কলেজ বা কোন প্রতিষ্ঠানের ভুমিকম্প বিষয়ক ড্রিল
- পরিবারের সদস্যদের সাথে কথা বলে
- এলাকার লোকজন/ প্রতিবেশীর সাথে কথা বলে
- ভূমিকম্প বিষয়ক অনুষ্ঠান/ কর্মশালার মাধ্যমে
- নিজে থেকেই জেনেছি
- সামাজিক যোগাযোগের মাধ্যম থেকে
- অন্যান্য (উল্লেখ করুন) ____

৩.৪ ভূমিকম্পের ঝুঁকি নিরসনে সক্ষমতা এবং সচেতনতা বৃদ্ধির জন্য নিম্নোলিখিত মাধ্যমগুলির মধ্যে কোন তিনটিকে সবচেয়ে বেশি পছন্দ করেন ক্রম উল্লেখপূর্বক প্রকাশ করুন

মাধ্যমের তালিকা	**ক্রম**
গণমাধ্যম ((টিভি / রেডিও ইত্যাদি)	
সংবাদপত্র/ লিফলেট	
বিভিন্ন সাংস্কৃতিক পরিবেশনা (নাটক / গান)	
ভূমিকম্প বিষয়ক এলাকা/ পাড়া ভিত্তিক সভা/ কর্মশালা	
ভূমিকম্প বিষয়ক ড্রিল/ ট্রেনিং	
অন্যান্য (উল্লেখ করুন) ________________________________	

৩.৫ আপনি কি আপনার এলাকার ভূমিকম্প ঝুঁকি সম্পর্কে জানেন?

- হ্যাঁ
- না

৩.৫.১ হ্যাঁ হলে, আপনার এলাকাকে ভূমিকম্পের জন্য ঝুঁকিপূর্ণ মনে করার জন্য নিম্নের যে কারণ গুলি প্রযোজ্য সেগুলিতে টিক দিন এবং প্রযোজ্য কারণ গুলোর মধ্যে সবচেয়ে গুরুত্বপূর্ণ তিনটি কারন চিহ্নিত করে তাদের ক্রম উল্লেখ করুন

সম্ভাব্য কারণ সমূহ	প্রযোজ্য হলে টিক দিন	ক্রম
ভৌগলিক অবস্থান এবং অবস্থা		
এলাকার মাটির ধরন ও প্রকৃতি (ভূতাত্ত্বিক অবস্থা)		
এলাকায় অনেক পুরানো ভবন রয়েছে		
অপরিকল্পিত স্থাপনা		
এলাকার ভবন এবং স্থাপনা সমূহ খুবই ঘনবসতি পূর্ণ		
খোলা জায়গার অভাব		
সরু রাস্তা		
এলাকায় অনেক জলাভূমি রয়েছে		
ভূমিকম্পের কারনে ভুমিধস হবার সম্ভবনা		
বৈদ্যুতিক দুর্ঘটনার কারণে আগুনের সম্ভাবনা		
অন্যান্য (উল্লেখ করুন)		

৩.৫.২ আপনার এলাকার ভূমিকম্প ঝুঁকি হ্রাস করার জন্য কি করা যেতে পারে বলে আপনি মনে করেন?

____-

৩.৬ আপনি যে ভবনে বাস করেন সেটি কি ভূমিকম্পের জন্য ঝুঁকিপূর্ণ বলে আপনি মনে করেন?

- হ্যাঁ
- না

৩.৬.১ হ্যাঁ হলে, আপনার এরুপ ধারনার পেছনে নিম্নের যে কারণ গুলি প্রযোজ্য সেগুলিতে টিক দিন এবং প্রযোজ্য কারণ গুলোর মধ্যে সবচেয়ে গুরুত্বপূর্ণ তিনটি কারন চিহ্নিত করে তাদের ক্রম উল্লেখ করুন

সম্ভাব্য কারণ সমূহ	প্রযোজ্য হলে টিক দিন	ক্রম
নিম্নমানের নির্মাণ সামগ্রী এবং নির্মাণ কৌশল		
অনেক পুরানো ভবন		
ভবনের দৃশ্যমান ফাটল		
জরুরি নির্গমন পথের অপর্যাপ্ততা এবং অব্যবস্থাপনা		
ভবনের নিচের মাটির ধরন		
ভবনের সাথে পার্শ্ববর্তী ভবনের স্বল্প ব্যবধান		
জলাভূমি ভরাট করে বানানো ভবন		
অন্যান্য (উল্লেখ করুন) ____		

৩.৭ আপনার কি ভূমিকম্পের অভিজ্ঞতা আছে?

- হ্যাঁ
- না

৩.৭.১ হ্যাঁ হলে, শেষ কত সালে ভূমিকম্প অনুভব করে ছিলেন ? ____________________

৩.৭.২ আপনি তাৎক্ষণিকভাবে কি করেছিলেন? (খোলা প্রশ্ন** এবং একাধিক উত্তর গ্রহণযোগ্য)

- কাঠের কিছুর নিচে লুকিয়েছিলাম
- দেয়ালের/ শক্ত পিলারের পাশে দাঁড়িয়ে ছিলাম
- মাথায় বালিশ, কম্বল ইত্যাদি নিয়েছিলাম
- পরিবারের সাথে ভবন থেকে নেমে রাস্তায় চলে গিয়েছিলাম
- ছাদে চলে গিয়েছিলাম
- ইলেক্ট্রিসিটি/গ্যাসের লাইন বন্ধ করেছিলাম
- ভয় পেয়ে গিয়েছিলাম
- কিছুই করিনি
- অন্যান্য (উল্লেখ করুন)____

৪। উত্তরদাতার ভূমিকম্প দুর্যোগ ব্যবস্থপনা বিষয়ক ধারনা

৪.১ আপনি কি ভূমিকম্প বিষয়ে পারিবারিকভাবে প্রস্তুতি নিয়েছেন ?

- হ্যাঁ

- না

৪.১.১ হ্যাঁ হলে, নিম্নোক্ত প্রস্তুতিগুলির মধ্যে কোনটি আপনারা গ্রহন করেছেন (একাধিক উত্তর গ্রহণযোগ্য)

- তাৎক্ষণিকভাবে ব্যবহার এবং সাথে রাখার জন্য প্রয়োজনীয় সরঞ্জাম একত্রিত করেছি
- ভূমিকম্প চলাকালীন অবস্থান করার জন্য বাড়ির ভিতরে অপেক্ষাকৃত নিরাপদ একটি জায়গা নির্ধারন করেছি
- পরিবারের সদস্যদের সাথে ভূমিকম্প হলে করণীয় বিষয় নিয়ে আলোচনা করেছি
- প্রতিবেশি এবং ভবনের অন্যান্যদের সাথে আলোচনা করেছি
- অন্যান্য (উল্লেখ করুন) ______________________________

৪.১.১ (ক) প্রথম বিবৃতিটির উত্তর হ্যাঁ হলে, ব্যবহার এবং সাথে রাখার জন্য নিম্নোক্ত কোন কোন প্রয়োজনীয় সরঞ্জাম একত্রিত করেছেন? (একাধিক উত্তর গ্রহণযোগ্য)

- ফার্স্ট এইড বক্স
- শুকনা খাবার
- পানি
- টর্চ লাইট
- টাকা
- হুইসেল
- অন্যান্য (উল্লেখ করুন) ______________________________

৪.১.১ (খ) দ্বিতীয় বিবৃতিটির উত্তর হ্যাঁ হলে, নিম্নের কোন স্থানটি/গুলোকে নিরাপদ হিসাবে বিবেচনা করেছেন?

- দরজার ফ্রেমের নিচে
- বীমের নিচে
- পিলারের পাশে
- দেয়ালের পাশে
- টেবিল/খাটের নিচে
- ছাদে
- সিঁড়িতে
- অন্যান্য (উল্লেখ করুন) ______________________________

৪.২ আপনি কি ভূমিকম্পের পর প্রয়োজন সাপেক্ষে আশ্রয়কেন্দ্রে যাবেন?

- হ্যাঁ
- না

৪.২.১ যদি হ্যাঁ হয় তবে আশ্রয়কেন্দ্র হিসেবে নিচের যে জায়গাগুলো আপনি পছন্দ করেন সেগুলোর পাশে টিক দিন। কোনটি পছন্দ না হলে টিক এর পরিবর্তে পছন্দ না করার কারনটি লিখুন। পরবর্তীতে নিম্নোলিখিত জায়গাগুলির মধ্যে কোন তিনটিকে সবচেয়ে বেশি পছন্দ করেন ক্রম উল্লেখপূর্বক প্রকাশ করুন

জায়গার নাম	**পছন্দ হলে টিক দিন / পছন্দ না করার কারণটি সংক্ষেপে লিখুন**	**শুধুমাত্র পছন্দের জায়গা গুলোর ক্রম**
খোলা জায়গা		
খেলার মাঠ		
শিক্ষা প্রতিষ্ঠান		
ধর্মীয় প্রতিষ্ঠান		
সরকারি প্রতিষ্ঠান		
অন্যান্য (উল্লেখ করুন) ______________________		

৪.২.২ যদি না হয়, তবে কেন যেতে চান না ? ____

৪.৩ ভূমিকম্পের পর আপনি/ আপনার পরিবারের কোন সদস্য কি স্বেচ্ছাসেবক হিসেবে কাজ করতে ইচ্ছুক?

- হ্যাঁ
- না

৪.৩.১ যদি হ্যাঁ হয় তবে স্বেচ্ছাসেবক হিসাবে আপনি/ আপনারা নিম্নলিখিত কাজগুলোর মধ্যে কোনগুলো করতে চাইবেন সেগুলোতে টিক দিন, যেগুলো করতে চাইবেন না সেগুলোতে টিকের পরিবর্তে কারণটি লিখুন। পরবর্তীতে টিক দেয়া কাজ গুলোর মধ্যে কোন তিনটি বেশি পপছন্দ করবেন ক্রম উল্লেখপুর্বক প্রকাশ করুন। (এক্ষেত্রে ছক ২.২ এর সদস্যক্রম অনুসরণ করতে হবে)

স্বেচ্ছাসেবী কাজের তালিকা	১ম সদস্য		২য় সদস্য		৩য় সদস্য		৪র্থ সদস্য	
	পছন্দ হলে টিক দিন / পছন্দ না করার কারণটি সংক্ষেপে লিখুন	পছন্দের কাজ গুলোর ক্রম	পছন্দ হলে টিক দিন / পছন্দ না করার কারণটি সংক্ষেপে লিখুন	পছন্দের কাজ গুলোর ক্রম	পছন্দ হলে টিক দিন / পছন্দ না করার কারণটি সংক্ষেপে লিখুন	পছন্দের কাজ গুলোর ক্রম	পছন্দ হলে টিক দিন / পছন্দ না করার কারণটি সংক্ষেপে লিখুন	পছন্দের কাজ গুলোর ক্রম
নিবন্ধন ও তথ্য সংক্রান্ত								
উদ্ধার কার্য								
ত্রাণ ব্যবস্থাপনা								
প্রাথমিক চিকিৎসা/ মানসিক পরিচর্যা								
আশ্রয়কেন্দ্র/ চিকিৎসাকেন্দ্র ব্যবস্থাপনা								

খাদ্য প্রস্তুতি ও ব্যবস্থাপনা								
অন্যান্য								

স্বেচ্ছাসেবী কাজের তালিকা	৫ম সদস্য		৬ ষ্ঠ সদস্য		৭ম সদস্য		৮ম সদস্য	
	পছন্দ হলে টিক দিন / পছন্দ না করার কারণটি সংক্ষেপে লিখুন	পছন্দের কাজ গুলোর ক্রম	পছন্দ হলে টিক দিন / পছন্দ না করার কারণটি সংক্ষেপে লিখুন	পছন্দের কাজ গুলোর ক্রম	পছন্দ হলে টিক দিন / পছন্দ না করার কারণটি সংক্ষেপে লিখুন	পছন্দের কাজ গুলোর ক্রম	পছন্দ হলে টিক দিন / পছন্দ না করার কারণটি সংক্ষেপে লিখুন	পছন্দের কাজ গুলোর ক্রম
নিবন্ধন ও তথ্য সংক্রান্ত								
উদ্ধার কার্য								
ত্রাণ ব্যবস্থাপনা								
প্রাথমিক চিকিৎসা/ মানসিক পরিচর্যা								
আশ্রয়কেন্দ্র/ চিকিৎসাকেন্দ্র ব্যবস্থাপনা								
খাদ্য প্রস্তুতি ও ব্যবস্থাপনা								
অন্যান্য								

৪.৪ আপনি কি আপনার ওয়ার্ডের ডিজাস্টার ম্যানেজমেন্ট কমিটির কাজের সাথে সম্পৃক্ত হতে চান?

- হ্যাঁ
- না

৪.৫ আপনি কি বর্তমানে আপনার ওয়ার্ডের আর কোন কমিটি/ সামাজিক কার্যক্রমের সাথে জড়িত আছেন ?

- হ্যাঁ
- না

৪.৫.১ যদি হ্যাঁ হয়, তাহলে সেটি কি উল্লেখ করুন ____

৫। ভূমিকম্পে ঝুকি নিরসনে বাড়িওয়ালার সম্মতি (বাড়িওয়ালার জন্য)

৫.১ যদি আপনার ভবন ঝুকিপূর্ণ হিসেবে চিহ্নিত হয় তবে আপনি ভবন ঝুকিমুক্ত করনে/ শক্ত করতে রাজি আছেন? (ধারনা করুন, ভবন শক্ত করনের জন্য ঝুকির উপর নির্ভর করে বর্তমান নির্মান খরচের ৫% থেকে ৩৫% পর্যন্ত খরচ হতে পারে)

- হ্যাঁ
- না

৫.১.১ যদি হ্যাঁ হয় তবে আপনার কোন ধরনের সহায়তার প্র্য়োজন আছে ?

- আর্থিক সহায়তা
- কারিগরী সহায়তা
- অন্যান্য

৫.২ যদি প্রয়োজন হয় তবে রাস্তা প্রশস্ত করনের জন্য আপনি কি আপনার ভুমির অংশ দেবেন ?

- হ্যাঁ
- না

APPENDIX E

Checklist for Survey of Temporary Shelter and Emergency Health Facilities

Checklist for facility buildings suitable for temporary shelter

For Educational Institution

- Number of Teacher
- Number of Students
- Number of Staff
- Time Period of Institution

For Community Center

- Capacity

Checklist for health facilities suitable for emergency response

- Number of Doctor
- Number of Staff
- Number of Bed
- Existing Facilities