CHAPTER I

INTRODUCTION

1.1 General Introduction

"Lifeline", the term denotes those types of facilities which are necessary for the effective functioning and wellbeing of any society. It is a vital structure for human life and urban function. Lifelines basically convey food, water fuel, energy, information and other materials necessary for human existence from the production areas to consuming urban areas. Due to modernization and urbanization such type of lifeline facilities (Transportation, water supply, telecommunication, electricity etc) are increasing day by day.

With unique geo-climatic conditions and rapidly growing population, Nepal has been bounded time and again by elements of nature as well human misdemeanors. Even today, natural hazards like flood, drought, landslide, earthquakes are not rare in the country (Khanal, 1996; Tianchi, 1996; Sharma, 1998). While the vulnerability varies from region to region, a large part of the country is exposed to such natural hazards, which often turn into disasters causing significant injury, deaths and destruction of property (Khanal et. al, 2007). The natural disasters bring on big economic loss. In an average, natural disasters lead to a direct economic loss of GDP and death of thousand of people every year (DWIDP, 2001). Earthquakes are short lived, and the most fearful natural hazards because of their sudden impact and devastation within a few seconds affecting immense losses of life and property. Earthquake disaster leads a huge negative effect on the sustainable development of the country.

Main frontal thrust, Main boundary faults and Main central thrusts lines are extending in parallel from east to west separating the Terai, the Mountain, the Siwalik, the lesser Himalayan, the higher Himalayan and the Tetheys Himalayan. That’s why; Nepal has a high earthquake disaster, risk and hazard (JICA, 2001). Earthquake disaster, in Nepal, is one of serious events that severely impact the fast growing population. Existing as well as new constructions in Nepal including those in the urban areas, vulnerability is very high largely due to the fact that the vulnerable elements are yet outside the formal sector or program that are supposed to control the increase of vulnerabilities (Dixit, 2003).

Loss of life and property can be avoided through appropriate planning, education and the construction of structures according to seismic code that sway rather than break under the stress of an earthquake. In this study, emphasis is given to seismic vulnerability assessment. The HAZUS multi hazard loss estimation methodology is considered for evaluating earthquake loss for lifelines in the study area for assessing vulnerability and risks.

Vulnerability maps are derived from estimation of various effects of seismic waves at the terrain surface, ground shaking, surface faulting, and liquefaction. GIS helps in analyzing large volume of data on active faults, geological structure, soil types, topography and infrastructure.

1.2 Statement of the Problem

Lifeline infrastructure is a highly valuable asset of a city. For example; road network plays a vital role in emergency responses, electricity for industry as well as domestic use. Thus, disruption of lifelines such as water supply or electric power for a city or urbanized region would inevitably lead to major economic losses and disturbed on public health and eventually population migration. It is therefore necessary to consider what has to be done to promote development and application of appropriate design and construction within urban area.

Lifelines are also highly intra- and inter-dependent systems. These can be damaged by collapsing houses or bridges or by landslides and riverbanks, the movement of which can be triggered by earthquakes. The malfunctioning infrastructure leads to immediate danger for people and longer threatening situations. However, most research focus on earthquake phenomenon rather than its possible impact (SLARIM, 2002). The impact of natural disasters such as earthquakes - which account for one of the highest losses amongst all types of disasters in terms of the number of people affected, the properties and infrastructure affected as well as the cost to the local, regional and global economy; is significant as well as alarming. The study indicates how vulnerable urban and regional systems (other than lifelines) are to the interruption of services like electricity, water, gas, and communication.

The population and infrastructure growth of Ilam are increasing at an alarming rate. The city has been expanding in a very improper manner having huge encroachment, lack of proper infrastructure facilities, unplanned urban development etc.

Furthermore, 90 percent of that population at risk will be in developing countries (UNDP, 2004). Hence, vulnerability assessment needs to be studied carefully and loss estimation needs to be undertaken particularly in the urban areas of developing countries which usually do not have disaster preparedness plans in place and where high concentration of population are benefited form services that are vulnerable to natural hazards such as earthquakes.

The threat of a potential natural disaster such as an earthquake looms large over the city. Earthquake occurrences in seismically prone areas cause colossal damage to housing and infrastructure and proved to be a major setback factor for urban areas – especially those that are located in highly seismic prone zones. The vulnerability of buildings and infrastructure systems depend on the type of risk involved, in combination with the physical (structural) characteristics of the buildings and infrastructure involved and factors associated with the environment. In every earthquake, vulnerability is heavily concentrated in the areas where the structures are of poor quality. In the context of vulnerability asset of lifeline infrastructure like road transportation, water supply, telecommunication, electricity etc; some of the research questions have been raised.

- What is level of vulnerability exposure to earthquake hazards- Road, Electricity, Water supply system, Telecommunication and Petrol pump?
- What is the level of Hazard which exposed to public services?

1.3 Objectives of the Study

The main objectives of this research are to find-out lifeline vulnerability assessment in an earthquake and sub-objectives have been set to answer the above stated research questions. The specific objectives of the present research are as follows:

- To find out level of vulnerability of lifeline services.
- To investigate the level of hazard of lifeline services.
- To generate damage maps of the lifeline services.

1.4 Significance of the Study

Nepal is facing a serious situation in reducing natural disasters. Disaster reduction strategy involves every human community, and almost every human endeavor. It also involves almost every physical phenomenon of the earth's surface. The main theme of strategy is to find a way to live with these phenomenon's, rather than die from them. The study somehow tries to fill the critical gap, which is useful to increase the ability of cities to reduce disaster risk.

The measures for mitigation of the impacts of potential future earthquakes disaster events demand multidisciplinary scientific findings. The accurate prediction of the exact time and geographical location is the effective tool and speedy solutions. Therefore, the availability of such findings may be useful to the proactive measure. The main contribution of this research is to provide better understanding of the socio-economic impacts of earthquake. That is resilient to the effects of natural disasters and to guide judgments about the extent of expenditure for mitigation. It will also be helpful for the policy makers, researchers, planners and social workers to know about their effect on this area. This paper is also useful for NGO/INGO's to conduct management program in the area.

Especially, this study has been based on a need to better understand the impact of disruption of lifelines from earthquakes and to assist in the identification and prioritization of hazard mitigation measures and policies. In addition, this paper is intended to improve national awareness of the important of protecting lifeline systems from earthquakes, and of assuring lifeline reliability and continued serviceability

1.5 Limitation of the Study

In this study, lifeline services such as Road Transportation, Electricity, Telephone line, Drinking Water and Petrol pump have been included. Lifelines of critical importance have been analyzed to estimate seismic vulnerability and to identify those lifelines having the greatest economic impact. The examined lifelines include road, electricity, bridge, telephone, petrol pump, water supply system and emergency services (Hospital, School). The estimated vulnerability is presented in terms of direct damage according to methodology utilized.

During the development of this report and its supporting data, several problems were encountered that could not resolved because of technical difficulties and lack of available data. For example, telecommunication systems, only location of cabinet and networking of telecommunication were included in this study because of unavailability data or need for more in-depth studies. The major limitation of the study is the limitation of time and resources for carrying out the field data collection.

Lifelines damage resulting from secondary effects such as landslides was also considered in developing this paper. It has been emphasized that this research is macroscopic investigation at the local level and the results are not used intending to evaluate any particular regional utility for lifeline. Field survey has been carried out to collect information about condition and location of different type of lifeline services.

1.6 Structure of the Study

This research paper is organized to find out the vulnerability condition of infrastructure including its theoretical background. It has been divided into seven chapters: The first one contains the introduction of the study. It includes general background, objectives, significant, limitation of study, and the structure of the report itself. It mentions how the study is linked with other parts of the study as well as extent of the study.

Chapter Second is about some methods developed by different institutions and brief review of the earthquakes effects and past efforts on the related on vulnerability assessment. It aims to discuss the previous works on the similar methodology that has been developed as the study is regarding.

The three chapter describes the research methodology that has been adopted to obtain objectives of the research. This chapter attempts to provide appropriate working definition of the technical terms used in this report along with a theoretical support. It also includes a discussion on GIS analysis that has been used for the study. It has six distinct subdivisions namely justification of selection of the study area, conceptual framework, source of information, HAZUS method, data processing system and analysis.

The next chapter describes the study area along with location and characteristics of it. It also includes brief discussion on lifeline services of the area.

Chapter five describes the field works (lifeline inventory) that has been taken place for the study. It includes basically primary data that have been collected during the field work including their format, level of accuracy and applicability to the study.

Chapter six is to describe the analytical part of the report. All the analysis has been done with their findings. This chapter analyses the field data with GIS analysis and draws conclusion on the basis of the analysis. It also uses the HAZUS method to find out the vulnerability condition into various scenarios.

The last chapter contains the recommendation and conclusion drawn upon this study.

CHAPTER II

LITERATURE REVIEW

Basically, literature review establishes the relationship of proposed research to previous and or ongoing research. Literature review also helps to find-out methodological gap as well as in the substantive aspect of existing research. More importantly, the review of literature in any study must be able to establish the relation of relevant knowledge and information. In this study, three types of literature have been reviewed. First part of literature review defined related term which has been used. Second part is about existing methods developed by different institutions on the similar field. At last, past efforts related to vulnerability assessment have been reviewed.

2.1 Literature Review of Theoretical Models and Concepts in Vulnerability Assessment

Several methods have been developed by different institutions to identify vulnerable conditions of the structures. The methods range from very simple to very complex and data demanding. Some of the methods are given below.

- A method developed by JICA (2001)
- A method developed by RADIUS (1996)
- A method of ATC-25 developed by FEMA

2.1.1 The Method Developed by JICA (2001)

This method was based on a Study on Earthquake Disaster Mitigation (SEDM) for Kathmandu. Road and bridge inventory maps were produced for whole Kathmandu valley and put into GIS database. This database includes four earthquake scenarios with MMI maps. PGA maps and liquefaction maps, roads and bridges are classified into different categories. Where road cross slopes are more than 50mm or high were taken as hazardous points (JICA, 2001). It is considered that a road segment likely to block/damage at slope failures. But to find out the bridge vulnerability, condition of bridge has been scored by the field reconnaissance and defined score 26 and above are more collapsed, score below 26 and above are taken as stable.

This method has been developed for city oriented study. It is very simple to calculate vulnerability condition based on road classification. The classification is based on function of roads, and the importance of road in an earthquake scenario is also considered.

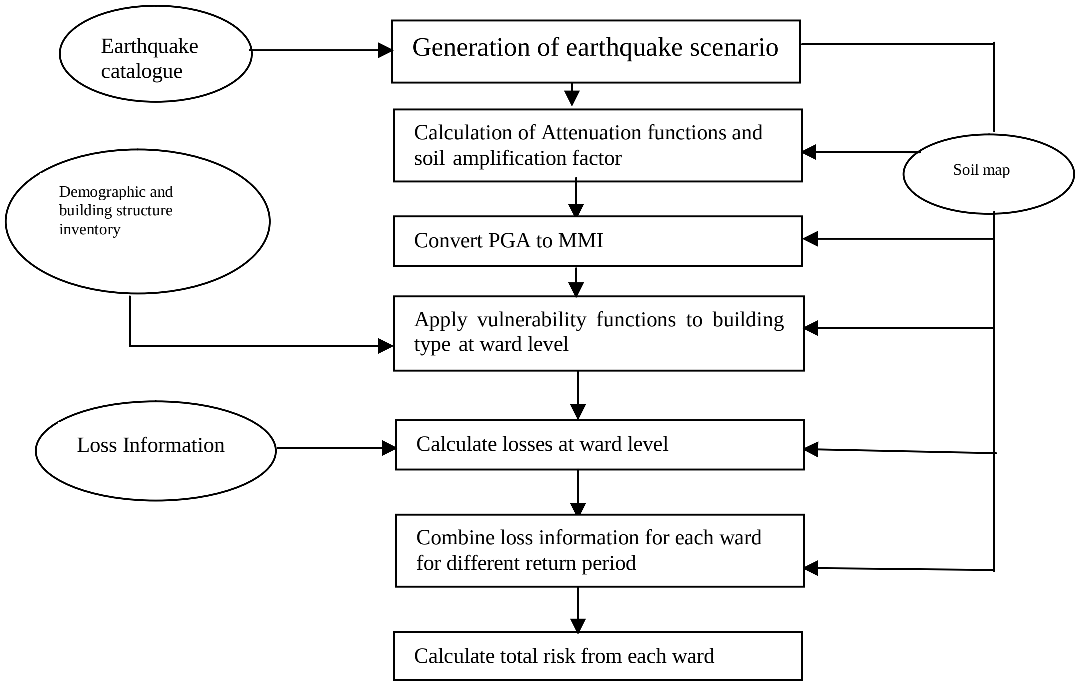
The vulnerability is evaluated based on probability of unstable slope failure not on structure of road and other factors such as landslide/ liquefaction of soil etc. If they are affected by the landslide, the road will be certainly high damaged than the slope.

Since the hazardous points are only, one has high slopes than 50mm. If the method is applied in a gentle slope area, there are not any hazardous points. Therefore, the methods need to be modified to make it applicable to individual city.

2.1.2 The Method of RADIUS

The method was developed by the IDNDR secretariat, UN Geneva in 1996 with financial and technical assistance from the government of Japan for reduction of seismic disasters in urban areas of developing countries. The main objectives of the project were to develop practical tools for urban risk management. This methodology has been developed and applied by GHI through actual projects in such cities such as Quito, Equador, and Kathmandu, Nepal. The estimation of the potential damage of an adopted hypothetical earthquake is carried out in two steps: theoretical and non-theoretical. The theoretical estimation is performed by combining the seismic intensity distribution that is estimated for the adopted earthquake with the inventory of the structures and infrastructure of the city. This combination is performed using vulnerability functions (See figure 2.1.2) that are developed to reflect the seismic behavior of the structures and infrastructure found in the city.

Figure 2.1.2: A Flowchart of the RADIUS Method



Source: Tung, 2004

Figure 2.1.2 shows the flow chart of Radius methodology. This methodology divides the building class into 10 categories based on their material type, construction type, seismic code, occupancy type and number of stories (Villacis and Cardona, 1999). This classification is based on the common building type in Latin American cities.

This method can be used for buildings and infrastructures losses at ward or Block level. The earthquake risk assessment process includes the following activities.

Vulnerability functions are determined as a function of acceleration/ MMI based on damage observed during past sample earthquakes (Villacis, 1999). The damage levels considered, in this method, are collapse and heavy damage.

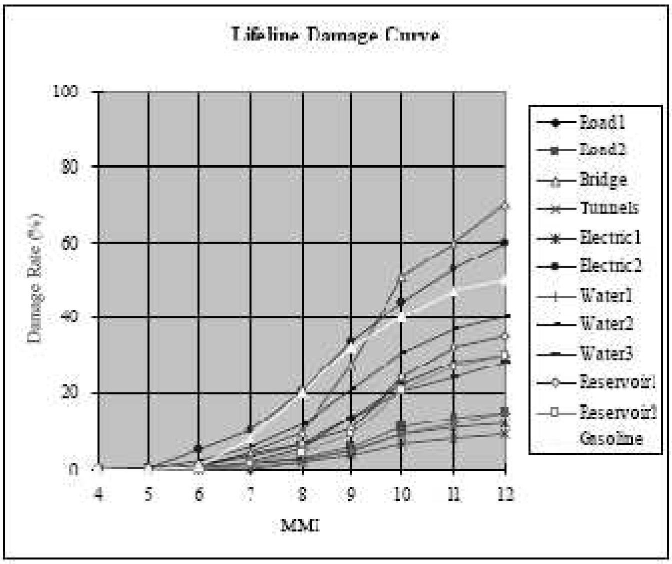
Vulnerability functions in vulnerability assessment includes two steps (Villacis and Cardona, 1999)

a) Identify all the existing structural and infrastructure types of the city and then select representative ones.

b) Existing vulnerability functions for the selected types are calibrated using data of past observed damage as well as the opinions and/or studies of local experts. For important and critical facilities, individual vulnerability studies are carried out.

The vulnerability functions used by RADIUS for lifelines or shown in Chart 2.1.2

Chart 2.1.2: Lifeline Damage Curve



Vulnerability functions used by RADIUS can be calculated according to classification of single type of infrastructures. This method is very simple and easy to use. The application of RADIUS varies from city to city. Those criteria were selected based on individual city. Based on the MMI value of all existing structural and infrastructural types of city, damage curves can be calculated. But, this method does not show where the location of damaged road is. Next, the result is more or less influenced by choosing a representative one.

The hazard parameter used in vulnerability function is MMI. However, selection of MMI is very subjective because it is based on descriptive measures of damage, whose performance may vary from one part of the world to another for the same level of ground shaking.

2.1.3 The Method of ATC-25 Developed by FEMA

According to method of ATC-25, the analysis of seismic vulnerability of lifelines system and the economic impact of disruption is based on assessment of three factors.

- Seismic hazard
- Lifeline inventory
- Vulnerability functions

These factors are used to quantify vulnerability and impact of disruption in terms of direct damage and economic losses resulting from direct damage and loss of function of damaged facilities. Estimates of direct damage to lifelines expressed in terms of percent replacement value and money losses.

Direct damage: It is defined as damage resulting from ground shaking or other collateral loss causes such as liquefaction. For each facility, it is expressed in terms of cost repair divided by replacement cost. Direct damage is also varies from 0 to 1 (o% to 100%). Direct damage can be estimated using-

- Estimates of ground shaking intensity according to seismic hazard model.
- Inventory data specifying the location and type of facilities affected, and
- Vulnerability functions that relate to seismic intensity and site conditions to expected damage.

The estimation of direct damage considers both damage resulting from liquefaction, landslide as well as resulting from ground shaking.

The analysis for computing direct damage due to ground shaking proceeded are as follows. For each earthquake scenario, MMI levels were assigned to each 25 km grid cell in the affected region. Damage states were then estimated for each lifeline component in each grid cell using the motion damage curves provided by vulnerability functions. The procedure for utilizing motion damage curves varied slightly according to facility type, depending on whether the lifeline was a site specific facility or a regional network of these lifelines.

Four damage states are considered in the method.

- Light damage (1-10% replacement value)
- Moderate damage (10-30% replacement value)
- Heavy damage (30-60% replacement value)
- Major to destroyed (60-100% replacement value)

The total number of affected facilities and the percentage of facilities are differing in each lifeline and scenario earthquake.

Site-specific Lifelines (Inventory Data): Direct damage to site specific i.e. lifelines that is point or line facilities (hospital, telephone cabinet, reservoir tank, telephone line) were inventoried defining the number of location and distribution of facilities. And number of facilities affected was estimated relationships between population and number of facilities.

Vulnerability Functions

The vulnerability functions developed for each lifeline consist of the following components.

- General information which consists of a description of the structure and its main components, typical seismic damage in qualitative terms and seismically resistant design characteristic for the facility and its components in particular.
- Direct damage information, which consists of a description of structure type and quality of construction(degree of seismic resistance) default estimated of the quality of construction for present conditions and corresponding motion damage curves, default estimates of the quality of construction for upgraded condition and restoration curves

Motion damage curves and restoration curves define expected lifeline performance for each of these regions and from the heart of the quantitative vulnerability analysis.

Seismic Hazard: It is the expectation of earthquake effects, which is usually defined in terms of ground shaking parameters (e.g. peak ground acceleration, modified mercally intensity, peak ground deformation, peak ground velocity).On the other hand, it can be defined in terms of landslides or liquefaction or other phenomenon resulting from an earthquake.

Seismic hazard is a function of the size, or magnitude of an earthquake, distance from the earthquake, local soils and other factors. Estimation of seismic hazards can be performed on deterministic or probabilistic basis (FEMA, 1999)

2.2 Literature Review of Past Efforts on Vulnerability Assessment on Lifeline Services

International institute for geo-information and earth observation (ITC) has launched a research project, strengthening local authorities in risk management (SLARIM). The main objective of this project was to develop methodologies for GIS based risk assessment and decision support systems for developing countries that can be beneficial for local authorities in medium sized cities of developing countries. As part of SLARIM research project, several studies have been carried out for Kathmandu valley. In this study, some of the past efforts to similar fields have been reviewed.

The Japan International Cooperation Agency (JICA, 2001) carried out a detail study on Earthquake Disaster Mitigation in the Kathmandu valley in 2001. In the JICA study, the base methodology was implemented with specific focus on the community based disaster mitigation, where communities were empowered through participatory decision making process.

Above previous works mentioned about the background efforts and methodologies, are treated as the suggestive and guidance materials. The studies in the related fields conducted out of the country are good to buy in the ideas.

Guragain (2002), the study on earthquake disaster mitigation in Kathmandu valley estimated high potential losses and casualty of medical facilities of Kathmandu Valley. Although this is a seismic country, earthquake resistant construction standards have not been applied, and special guidelines have not been considered for hospital facilities in general. For these reasons, there is high possibility of hospital buildings of not functioning after a large seismic event.

This study was conducted by NSET-Nepal with collaboration of NGO/INGOs. The result of study was qualitative assessment of 14 hospitals and quantitative assessment of one hospital. If an earthquake of MMI VII level of shaking occurs, 40% hospitals might be functional, 30% partially functional, 50% out of services and about 10% of the hospital might collapse.

Marco et. al. (2002) estimated the vulnerability of lifelines. The main objective of this study is to determine the seismic hazard for pipeline services in Bercelona. This work includes lifeline database preparation, development of seismic scenarios, computation of direct damage for each seismic scenario, and the graphic representation of all these systems using a GIS system. The seismic response of pipeline differs for each structure. The main factors that cause pipeline system damages due to earthquakes are ground shaking and ground faults. Two type of vulnerability models are included in the study. Wang model which considers liquefaction effects and another is the Eguchi model which includes both the impact of ground shaking and deformation failure. Four type of damage (slight, moderate, extensive and complete) has been categorized. Applying Eguchi model to Bercelona, he shows that for intensities below 6 there are no breaks, for intensities between 6 and 8 there is a moderate number of breaks and for greater intensities there is higher number of breaks up to catastrophic cases for intensities 11 and 12. and using Wang model shows that for intensities below the damage is slight, and 5 the damage is destructive.

Menoni et. al. (2002) studies concerning lifelines response to earthquakes especially in Lombardia region, Italy. For the study, this large area has been subdivided into three regions. At first, the characteristics of the lifeline systems of the area have been surveyed and the analytical forms filled with the acquired information. Then the vulnerability index has been calculated. The comprehensive model has been developed for assessing lifeline seismic vulnerability. It addresses not only physical factors, but also organizational and function.

The main theme of this study was to search vulnerable elements within each utility system and between the latter and the external environment. The results show that the most vulnerable area is that of Salo, which is threatened by several landslides, it may obstruct not also main road but also networks running beneath.

Based on the analysis of seismic vulnerability assessment of public schools, **Dixit et. al (2002)** estimated the hazard due to the great earthquake for Kathmandu valley. The main finding of this study is that, more than 60% buildings are built using traditional materials, which behave very poorly during earthquakes? And remaining 40% buildings use modern materials such as brick and cement. Even though modern materials are stronger, the Nepali schools are not safer. Local and traditional artisans built without engineering ideas. These buildings are taller, have longer rooms and longer windows and doors. These features make buildings as dangerous as the traditional ones. Among total 700 school buildings, only 3 buildings are, constructed according to Nepal national building.

Tung (2004), Calculated road and bridge vulnerability of Lalitpur city on the basis of their location, structure, design code, physical condition, age, construction, material and distance to road from buildings .He has developed MMI map, liquefaction maps and calculated spectral acceleration values of the study area. He has used Radius and Hazus method to find out vulnerability assessment in different earthquake scenarios. He finds out that 20% of the total road both ashaphalt and non-ashaphalt will damage.

But he has not identified the locations of the damaged roads. On the other hand, the Manahara and the Bagmati south bridge have highest probability of complete damage. Meanwhile, Thapathali new bridge has the lowest probability of damage.

Guragain (2004), in his M.SC. research paper GIS for building loss estimation in Lalitpur sub metropolitan city, has concluded that roads are blocked by collapsed buildings. The debris of collapsed buildings occupies the road surface, reducing speed or preventing the vehicles from traveling due to the fact that buildings are very close to the roads. Furthermore, most buildings are not well constructed according to standard codes. Those buildings have high probability of collapsing once an earthquake happens.

Islam (2004), studied on population vulnerability of Lalitpur sub metropolitan city on the basis of building loss estimation by Guragain(2004). This study was carried out with objectives to determine what factors are determining to population vulnerability. He also developed a method for the estimation of population distribution, both in space and time. The whole study has mainly three components, identifying the homogeneous units of buildings, estimating the spatial and temporal distribution of population and estimating the number of casualties incase of and earthquake. The distribution of population has been converted to the number of casualties based on the building vulnerability. Using Hazus method, the study shows that 16 different spatial distribution of different casualty for each earthquake scenarios.

Jimee (2006), Using three different earthquake intensities. And building information such as age, construction, material, number of floors, space use and type, has researched on building damage and population vulnerability of ward 20 of Lalitpur Sub-metropolitan city. He concluded two types of building damage; partial damage and complete damage. He find out that due to an intensity ix earthquake, 26% buildings have high probability of damage or collapse. In the same way, casualties in different severity levels were estimated for different individual buildings due to possible earthquakes in different time periods; morning, day, evening and night. Thus, assuming intensity of ix and x, at daytime about 1602 and 401 causalities were estimated respectively.

Gulati (2006) studied with an aim to analyze the applicability of HAZUS model for risk assessment buildings in India, Dehradun. The whole research work was divided into four sections; Review of risk assessment methods, hazard identification and generation of the dataset (seismic, ground motion, building response and damage functions) included in the study.

The Reinforced Masonry (RM) and Unreinforced Masonry (URM) model classes from HAZUS have been selected as most representative buildings in the study. By applying HAZUS methodology, he has been developed damage probability matrix for four building types. Finally, risk assessment have been evaluated in terms of damage probability. Four type of damage (slight, moderate, extensive and complete) have been examined.

He concluded that HAZUS method does not give very realistic results for earthquake risk evaluation in study ward. Further, he mention that this method gives good results at the broad level in a risk assessment. So, he suggest to modify Hazus method to get accurate results in an Indian context.

Westen (2007) has estimated seismic loss estimation for Lalitpur, Nepal under the SLARIM project. The main objective of the study was to develop spatial information system for municipalities, which will allow local authorities to evaluate the risk of natural disaster in their municipality, in order to implement strategies for vulnerability reduction. The methodology concentrates on the application of methods for hazard assessment, elements at risk mapping, vulnerability assessment, risk assessment and the development of GIS based scenarios for varying hazard scenarios and vulnerability reduction options, using structural and non-structural measures. In this development of elements at risk, database use is made of interpretation of high resolution satellite imagery, combined with extensive field data collection using mobile GIS.

2.3 Earthquakes Effect on Lifeline Services

Earthquake damage is defined as damage resulting from ground shaking or other factors such as liquefaction and landslide. For each facility, it is expressed in terms of cost of repair divided by replacement cost and that varies from 0 to 1 (0% to 100%) (HAZUS99, 1999).

Earthquake damage is fundamentally a random phenomenon. An earthquake effect depends on a distance to the earthquake, the magnitude, the depth of hypocenter, the rock types and structure soil between the hypocenter and the site, and the local soil and topographical conditions. In general, the damage is always considered parallel with the type of hazard phenomenon. Survival of lifelines depends on their seismic performance characteristics. Besides, and earthquake also induced secondary type of hazard like tsunami, fire or landslide etc which sometimes are the reasons for many failure of infrastructure. The effects triggered by an earthquake sometimes cause more serious damages to elements at risk than the ground shaking of the quake itself. There are various types of earthquake damage according to different types of infrastructures.

2.3.1 Effect of an Earthquake to Road Transportation

Road transportation damage can result from failure of the roadbed or failure of an embankment adjacent to the road. Roadbed damage can take the form of soil slumping under the pavement and settling, cracking, heaving of pavement. Embankment failure may occur in combination with liquefaction, slope failure or failure of retaining walls. Such damage is manifested by misalignment, cracking of the roadway surface, local uplift of subsidence, bucking or blockage of the roadway. Sloping margins of fills where compaction is commonly poor are particularly vulnerable to slope failure. Road transportation also could be blocked by damaged buildings, broken underground water and sewer pipes.

An earthquake may harm road in various levels ranging from minor cracks on the top surface to completely ruptured road surface, large potholes. The road surface may also be damaged by slight deformation of base layers. The damage is about less than one inch along with crazing, long cracks also can be seen. Swallow potholes also appeared. These minor damages might not directly affect the function of road, but indirectly degrade the road quality in a long term period. This type of damage requires slight maintaining activities, and vehicles still able to travel on. However, sometimes the whole road section structure is collapsed. So, the road segment is completely malfunctioned requiring reconstruction.

Sometimes, the road surface is still in good condition. There are other types of effect that affect the road functionality caused by earthquake induced hazard like landslide, or debris fell on to the road surface. The road can be blocked by landslide or trees falling down on the road section. The earthquake created stresses that make weak slopes fail. The road can be used again as long as the debris is removed. This type of damage is usually seen in mountainous or hilly region.

Photo 2.3.1A: Road Blocked By Landslide, Kobe Japan

Source: NSET, 2008

Similar to landslide, there is another type of road blockage happening in urban areas. Debris of other collapsed structures along the road (building, electric wire etc) falls down on the road. The road structure is not severely damaged, but only slight damage of road surface can be seen. The roads are unusable for transportation. The road is not physically damaged rather it is damaged functionally by other ruined types of infrastructure.

Photo 2.3.1B.: Road structure Collapse, Kobe Japan

As in figure 2.3.1B, a crane and several construction vehicles lay toppled on a fractured road in Kobe, Japan, after a 7.2-magnitude temblor shook the quake-prone country. The Great Hanshin Earthquake Disaster of 1995 was one of the worst in Japan's history, killing 6,433 people and causing more than $100 billion in damages.

Photo 2.3.1C: Road blocked by House Debris, San Fransisco

Source: NSET, 2008

In figure 2.3.1C, it can be seen that the road was blocked by house debris. Workers position support beams to steady titling homes in San Francisco's Marina District after a disastrous earthquake hit the city in 1989. The 7.1-magnitude earthquake buckled highways and bridges, crushed cars, and toppled homes and buildings throughout the city.

Photo 2.3.1D: Bridge Collapsed, Guatemala City

Source: NSET, 2008

As shown in figure 2.3.1D, in the year 1976 earthquake near Guatemala City shattered this bridge in Agua Caliente, cutting off the city’s main supply route to the Atlantic. The 7.5-magnitude quake killed more than 23,000 people and left thousands more injured and homeless.

2.3.2 Earthquakes, effects on Water Supply System

Earthquakes might break pipes that supply water for household purposes and also sewage lines. Diseases might spread due to lack of proper sanitation and hygienic conditions that might exist in open air camps. At an earthquake, the first effect is vibrations of the ground. Reservoir tanks are mainly affected by them. With regard to pipelines, damage is more likely caused by landslides, rock falls, and ground movements. These are referred to as secondary effects of earthquakes. Therefore, any strategy of pipeline protection against earthquakes should emphasize on these secondary effects.

The performance of pipelines is strongly dependent on whether or not the supporting or surrounding soil fails. Failure of a piping system resulting from inertial loads is only rare, more typically severe ground failure (landslide, liquefaction, faulting) causes damage. Regional uplift can alter the hydraulic characteristic of a transmission system. Pipe damage is most common in soft alluvial soils or at interfaces between soft and firm soils. Types of pipe damage include bending or crushing of the pipe, shearing of the pipe, circumferential and longitudinal cracks and joint failure. Damage has been substantial at locations of local restraint such as penetrations to heavy surface structures (including manholes), tees, and elbows- water hammer induced by ground motions can cause damaged by temporarily increasing pressure in pipelines.

Underground pipelines and distribution pipelines (between 4 and 20 inches in diameter) are generally more susceptible to damage because of their construction.

Generally pipelines are located along with sewerage. Drinking water spill caused by a leaking pipe or may be polluted. In this situation, people suffer from diseases like cholera and loss of life and property.

Photo 2.3.2: Earthquakes Effect on Water Supply System

Source:NSET,2008

Source: NSET, 2008

2.3.3 Earthquakes Effect on Electricity System

Earthquake can rupture electric wires and lead to short circuits. Many homes have cooking gas cylinders or receive piped cooking gas. These can be damaged by falling debris. Electric systems are more likely to be seriously damaged by rock falls, landslides and collapsing structures than by ground shaking. When slides do occur, electric poles may be damaged. The control house may experience generic building damage ranging from dropped ceiling tiles and crack in walls and frames to partial and total collapse. Substation equipment and ceramics, in particular, are vulnerable to damage. Higher voltage ceramics tend to experience the most damage.

Generally, reducing slopes areas can reduce vulnerability. Transmission towers and the lines they support are particularly subject to damage through secondary effects such as landslides and rock falls, liquefaction and other ground failures. It is possible that the conductors supported by towers can slap each other and burn down. Ceramics used on transmission towers typically perform well in earthquakes because they are in compression rather than in tension or bending. Fault slippage is unlikely to damage underground lines because transmission lines have a thick wall, welded steel pipe jacket. Seismic loads do not generally have much influence on the design of transmission lines and towers. The towers are designed to withstand heavy wind and ice loads, as well as loads due to broken wires.

Transformers are large and heavy pieces of equipment that are frequently unanchored or inadequately anchored. Transformers may shift to the attached conduct, break bushings, damage radiators and spill oil. Transformers are typically damaged only by soil failures. Porcelain bushings, insulators, and lighting arrestors are brittle and vulnerable to shaking and are frequently damage. Major damage to electrical substations includes overturning of extra high voltage (EHV) transformers.

Towers and poles are generally undamaged except by secondary effects such as landslides, liquefaction and other ground failures. Conductors lines swinging together can cause burn outs and (or start fires). Settlement of soils with respect to manholes can sometimes cause underground line routed through the manhole to fail.

Photo 2.3.3: Electric Tower Damaged By Earthquake Shaking

Source: NSET, 2008

2.3.4 Seismic Damage on Petrol Pump

On-ground oil storage tanks are subject to a variety of damage mechanisms, including, failure of weld between base plate and wall, rupture of attached rigid piping because of sliding or rocking of tank

CHAPTER III

RESEARCH METHODOLOGY

Research methodology provides a whole framework for selecting research gap; analyzes order and exchange of information for a particular issue. The research is always based on collection and analysis of data which are processed to fulfill research questions. To conduct a research in a systematic way requires a method. Methods are sets of techniques or identifying a topic, receiving the related literatures, conducting fieldwork and writing a report. Many initiatives have been launched worldwide to assess and reduce urban vulnerability, such as risk assessment tools for diagnosis of urban areas against seismic disasters (RADIUS, 2000) in which the material properties vary. However, still one of the major issues is how hazards, vulnerability and risk assessments can actually be used, and in practice to reduce risk.

Data is primary input for identifying hazard prone area, vulnerability as well as risk assessments and disaster impact analysis. For any cities data relevant for risk analysis are unavailable or their quality and accuracy does not reflect a comprehensive picture of the situation at hand. There is a need to work towards the standardization and systematization of all issues related to the accuracy, technical soundness, methodologies and process related to the collection, analysis, storage and maintenance of data. This chapter clarifies the methodological approaches applied and put forwarded description on how information was collected and analyzed.

3.1 Terms Defined

Emergency: An emergency is a deviation from planned or expected or a course of events that endangers or adversely affects people, property or the environment.

Disaster: A serious disruption of the functioning of a community or a society causing widespread human, material, economic or environmental losses. Disasters often result in great damage, loss or destruction. Disasters occur when hazards meet vulnerability (Blaikie et. al, 1996). Disasters can be characterized by the scope of an emergency. An emergency becomes a disaster when it exceeds the capability of the local resources to manage it.

Hazard: Hazard generally refers to physical characteristics that may cause an emergency or potentially damaging physical event, phenomenon or human activity which may cause loss of life and property damage (Smith, 2001). For example, earthquake faults, active volcanoes, flood zones, landslide prone areas and highly flammable brush fields are all hazards.

Hazards can include latent conditions that may represent future threats and can have different origins-geological, hydro-metrological, biological, human and technological process (UNDP, 2004). Hazards can be combined in their origin and effects. Each hazard is characterized by its location, intensity, frequency and probability. Earthquake hazard is usually expressed in probabilities of occurrence of certain earthquake (ground shaking) in a time.

Earthquake Hazard: An earthquake is a sudden shift or movement of the earth's crust caused by the release of stress accumulated along geologic faults or volcanic activity (Pandey, 1999). On the surface, this is manifested by a moving and shaking of the ground, and can be massively damaging to poorly built structures. The most powerful earthquakes can destroy even the best built of structures. Most earthquakes occur at fault zones where tectonic plates collide against each other. They are capable of killing hundreds of thousands of people. Earthquakes, also called temblors (OALD, 2007), can be so tremendously destructive; it's hard to imagine. They occur by the thousands every day around the world, usually in the form of small tremors.

Magnitude and intensity are two measurements to identify physical strength of earthquake.

Earthquake Magnitude: The magnitude of earthquake measures the total seismically released energy, so it must also be related to ground acceleration of the area from where the energy is released.

Earthquake Intensity: The effect of earthquake is assessed in terms of intensity. Intensity refers to the severity of ground shaking experienced at site. It is subjective measurement; however it includes all the earthquake variables which are magnitude, hypo-central distance, attenuation media and local enhancing factor. It is generally greatest near the epicenter and decreases outwards from it. Intensity is usually expressed on the Modified Mercalli Intensity scale which ranges from I to XII. Earthquake magnitude and their effect has been given in Table3.1.

Table 3.1: Scale of Earthquake Intensities and Approximately Corresponding Magnitudes

Intensity(MMI)	Description of characteristic effect	Maximum Acceleration (g)	Magnitude (Richter Scale)
I	Instrumental: detected only by seismometers	0.001	
II	Feeble: notice only by sensitive people	0.0025	
III	Slight: like the vibrations due to a passing truck, felt by people at rest, especially on upper flowers.	0.005	3.5 to 4.2
IV	Moderate: felt by people while walking, rocking of loose objects including standing objects	0.01	4.3 to 4.8
V	Rather strong: felt generally; most sleepers are awakened and bell rings	0.025	
VI	Strong: trees sway and all suspended objects swing: damage by overturning and falling of loose objects	0.05	4.9 to 5.4
VII	Very strong : general alarm: wall cracks, plaster falls	0.1	5.5 to 6.1
VIII	Destructive: car drivers seriously disturbed, masonry fissured, chimney falls, poorly constructed building damaged	0.25	6.2 to 6.9
IX	Ruinous: some houses collapse where ground begins to crack and pipes break open	0.5	
X	Disastrous: ground cracks badly, many building destroyed and railway lines bent, landslides on steep slopes	0.75	7 to 7.3
XI	Very disastrous: few building remain standing, ridges destroyed, all services(railway, pipes and cables) out of action, great landslides and floods	1.0	7.4 to 8.1
XII	Catastrophic: total destruction, objects thrown into air, ground rises and fall in waves		>8.1

Source; (Pandey, 1999)

Scientists assign a magnitude rating to earthquakes based on the strength and duration of their seismic waves. A quake measuring 3 to 5 would be considered minor or light; 5 to 7 is moderate; 7 to 8 is major, and 8 or more is great.

Risk: Risk is the probability of harmful consequences or expected loss (Khanal et al., 2007). Another definition of Risk is the potential or likelihood of an emergency to occur. Risk results from the interaction between natural/ human induced and vulnerable conditions. For which can be calculated by the equation.

$$Risk = hazard * vulnerability / capacity$$

Risk Assessment/ Analysis: A process to determine the nature and extent of risk by analyzing potential hazards and evaluating existing conditions of vulnerability/ capacity that could pose a potential threat or harm to people, property, livelihood and the environment on which they depend.

The process of conducting a risk assessment is based on review of both technical features of hazards such as their location, intensity, frequency and probability and also the analysis of physical, social condition while taking particular account of the coping capabilities portrait to the risk scenarios.

Vulnerability: Vulnerability is a set of conditions and process resulting from physical, social, economical and environmental factors which increase the susceptibility of a community to the impact of hazards, (UNDP, 2004). Positive factors that increase the ability of people and the society they live in to cope effectively with hazards that increase their resilience or reduce their susceptibility are considered as capacities.

3.2 Justification of the Selection of study Area

Lifeline services are mostly concentrated in the city or urban area. It indicates that the effect of earthquake would more on urban area than the rural area. To reduce earthquake disaster, NSET- Nepal has launched municipal risk identification programme in Nepal. Therefore, this study has been done on Ilam municipality as a requirements of NSET-Nepal.

The city is the gateway to Mechi zone of Nepal and Queen of Hills. It is also a market place for surrounding hilly regions. Besides, it is an educational center with some of the best and well known schools in the country located in the city. Apart from schools, many national and international level institutions are located in the city. The city is a service city. Moreover, it is an administrative city and the headquarter of district and Mechi zone itself.

Ilam municipality was established in 2015 B.S. It is located in eastern part of Nepal. The municipality encompasses 27 sq km. It consists 9 wards with having population 16246(MuAN, 2007). Geographically, it lies in 26^0 54′ 0″ N longitude to 86^0 56′ 25″ E latitude. It is bounded by Maikhola, Puwakhola, Sarki and Ujeli khola and, Sangam point of Maikhola and Ujelikhola in east, west, north and south respectively. The annual growth rate of population is 3 %(CBS, 2001). Ilam municipality, being the headquarters and the center of commercial and administrative activities for the entire district, this rapid growth of population and subsequent urbanization demands effective urban planning and enhanced urban infrastructure and services.

3.3 Application of Geographical Information System (GIS)

Geographic information system is computer system that records, stores, and analyzes information about the features that makes up the earth surface (Arc View GIS Manual, 2004). A GIS can generate two or three dimensional images of an area showing such features like hills, road with power lines. In this study, researcher used GIS to prepare vulnerability maps by making precise measurements gathering data and testing ideas.

Many GIS database consists of sets of information called layers. Each layer represents particular types of geographic data. For example the layer may include information of roads in an area. Another layer may contain information of water supply in that area, while another records building structures. The GIS can combine these layers into one map showing how the roads, electric line, water supply networks and building structure relate to one another so that policy makers could use this composite map determine whether a particular part of a road is more likely to crumple.

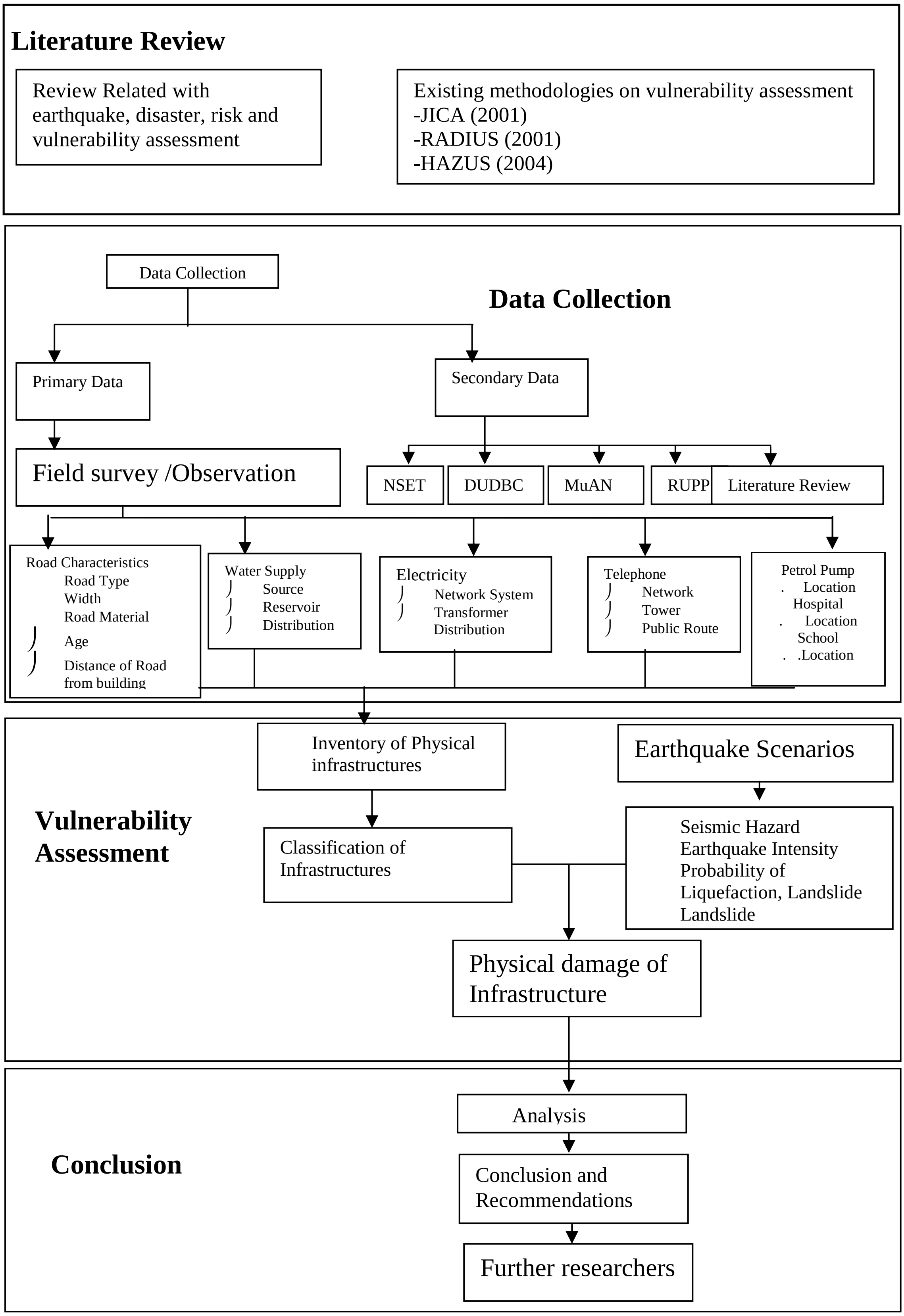
As GIS is used to accept geographic data from a variety of source including maps, satellite images, aerial photographs, printed text and statistics, GIS sensors can scan some of this data directly. For example, a computer operator may feed a map or photographs into scanner and the computer reads the information it contains. The GIS converts all geographical data into digital code and arranges it in database.

3.4 Conceptual Framework of the Study Methodology

This study is concerned with the seismic risk to lifelines and provides the direct effects of lifeline interruption due to earthquakes.

The research methodology has been conceptualized in the form of flow chart in the figure 3.4

Figure 3.4 Flow Chart of the Study Methodology



The whole research work has been divided into four major parts. The first part of the methodology deals with the literature review of general terms related to ERA and review of various ERA methods available in other countries. The second part deals with the identification and generation of data required for ERA in Ilam using the HAZUS. The third part deals with the evaluation of HAZUS, Infrastructure inventory classification and possible modification to use it for ERA in Ilam city. The fourth part of the methodology includes the analysis of applicability of the HAZUS model in an area of Ilam.

Generation of the Dataset

The countries Municipality did not have a GIS section, nor did they have GIS data on the service structure within their municipality. A series of 1:25000 Topo-maps in AutoCAD format were converted into a GIS database, consisting of separate layers for buildings, roads, contours and drainage. Field observation was used to characterize of these type of infrastructure according to age and material.

Soil Response Modeling

In order to analyze the seismic hazard, a subsurface database was generated for the Ilam municipality. Geological map and soil map prepared by Chamlagain et. al. (2002) was used for storing the information. This all sediments of the basin were divided into four types. The depth of each of the layer boundaries, including the surface elevation was used in GIS and Digital Elevation Models of each of these surfaces were obtained through point interpolation.

The GIS layers were used for one- dimensional calculations of the ground response. Three earthquake scenarios were selected. The results were calculated as Peak Ground Acceleration.

Loss Estimation

For analyzing seismic vulnerability, each type of services has been divided into various classes. The vulnerability curves, developed by HAZUS99, are used. For each MMI class and service type, minimum and maximum values of services are given in the percentage that would be heavily damaged (collapsed or un-repairable) or partly damaged (repairable, and available for temporary evacuation).

The earthquake intensity maps were used in combination with each type of services. Each and every earthquake intensity map and the vulnerability curves are used to calculate the range of completely and partly damaged services.

3.5 Sources of Information

Initially, government offices, professional organizations and individuals were contacted in an effort to identify databases, especially spatial data in an electronic form. Some organizations had previously furnishes the information. As a result, DUDBC database became a major source for spatial data of several lifelines. A significant portion of these data consist of digitized topographical maps performed by survey department of Nepal. Beside this, other type of Primary and Secondary sources were employed in various ways, which are summarized below.

3.5.1 Field Survey

Different type of information especially Attribute data related with lifeline services such as roads, telephone, electricity, water supply and petrol pump were gathered during the field visit.

Road Network Data: The names of roads, width, construction material, status, types etc were obtained during field visit. The roads were named on map based on these documents provided by Ilam municipality.

Electricity System: The details of electricity system is available with the Nepal electricity authority(NEA), Ilam division .Electric lines distributional, pole material and transformers capacity ,their locations were delineated on map under the supervision of overseer of NEA Ilam division during the field visit. Electric pole distance from road, house and potential hazard near transformers were also observed and noted at the time of filed visit.

Water Supply: water supply system and network is available only as schematic diagrams prepared by the municipality staffs. Water supply system and networks were delineated on map during field visit. The water supply system contains details of pipe material, type of tank, pipe joint, pipe diameter, network; sources along with capacities were delineated under the supervision of overseer of Ilam municipality.

Telephone Network: The network system contains distribution lines and telephone cabinets which were represented on map under the supervision of technical personal from Nepal Telecom, Ilam Division. Site and situation of cabinet, pole material were also observed during field visit.

3.5.2 Secondary Sources of Information

Research Reports, Journal and Documents: The information on particular hazard published by different institution and author were also compiled and analyzed.

3.6 Data Processing

The available attribute data from primary and secondary sources has been processed by using computer software package: Excel. All spatial data has stored in arc view 3.2a with single geo-reference topographical map of study area.

3.7 Data Analysis

According to HAZUS method, each facility required for analysis include the geographical location (latitude and longitude), classification and replacements cost of the system components. The system also requires the length and point of each facility. For example roadways are classified as major roads and urban roads. Major roads include interstate and state highways and other roads with four lanes or more (HAZUS99, 1999). Urban road include intercity roads and other roads with two lanes.

Public infrastructures have been tabulated to and characterized the infrastructure. GIS used for assessing the spatial and attribute characteristic of services. Furthermore, the data were present in the form of diagram, chart, and table and visualize them in maps.

The analysis of seismic vulnerability of lifeline systems is based on an assessment of three factors.

- Seismic intensity on geological condition
- Soil liquefaction
- Slope instability
- landslide

In this study, these factors are used to identify vulnerable condition and impact of disruption in terms of direct damage. Estimates of direct damage to lifelines are expressed in terms of percent value.

Direct damage is defined as damage resulting from ground shaking, landslide, liquefaction and debris block (building damage). For each facility damage may be vary from 0 to 1 (0% to 100%). It has been divided into four categories- none, slight/minor, moderate, extensive.

In this study it is estimated using-

- Estimates of ground shaking intensity provided by the seismic hazard model.
- Inventory data specifying the location and type of facilities.

And, vulnerability condition that is related to seismic intensity and site conditions to expected damage. The analysis approach for computing direct damage due to these factors have been proceeded as follows,

- For each earthquake scenario, intensity map were assigned to each location and, damage states were then estimated for each affected lifeline component (point or line)

After damage due to ground shaking, landslides were established for each facility and the total direct damage for each facility was calculated.

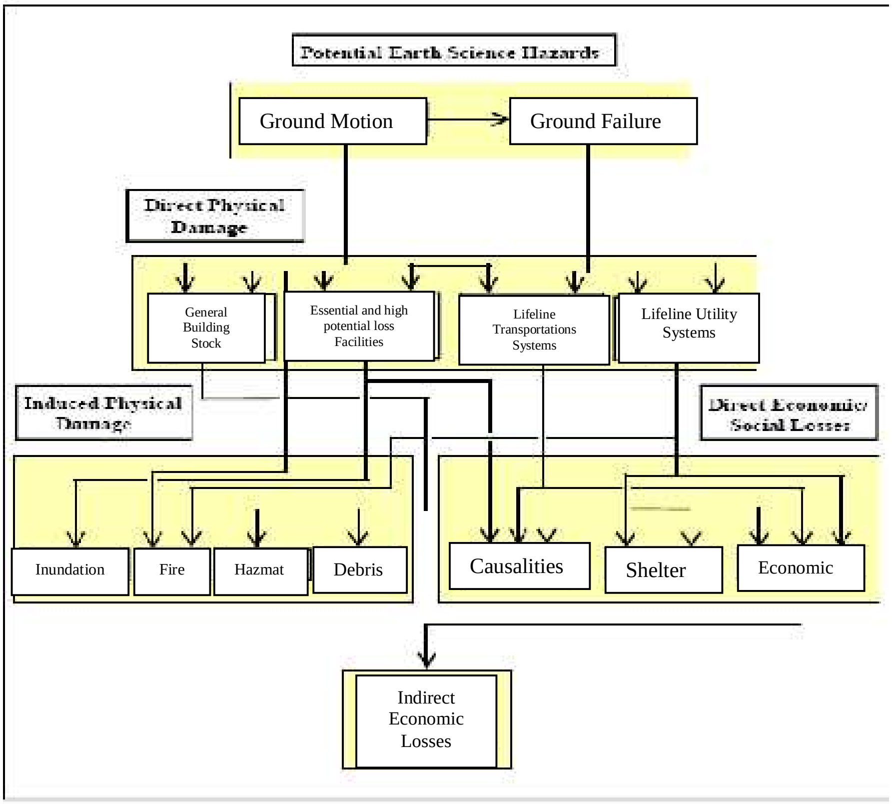
3.8 Method of HAZUS Developed by FEMA

United states Federal Emergency Management Agency developed HAZUS method to provide individual, business, and communities with information and tools to work proactively to mitigate hazards and prevent losses resulting from disasters.

Using GIS technology, HAZUS allows users to compute estimates of damage and losses that could result from an earthquake to support FEMA's mitigation and emergency preparedness efforts. HAZUS is being expanded into HAZUS-MH, a multihazard methodology with new modules for estimate potential losses from wind and flood hazard. In addition to estimating losses, HAZUS contains a database of economic census, building stock, transportation facilities, local geology and other information that can be used for a number of steps in the risk assessment process.

The framework of the method includes each of the components shown in figure: potential earthquake hazard, inventory, direct physical damage, induced physical damage, direct economic/social loss and indirect economic loss. These factors are independent with each other. In general, each component will be required for loss estimation. However, the degree of sophistication and associated cost will vary greatly by user and application. It is therefore necessary and appropriates that component in multiple levels.

Figure 3.8: The Overall Framework of the HAZUS Method



Source; Hazus99, 1999

3.8.1 Potential Earth Science Hazard (PESH)

A potential earth science hazard includes ground motion, ground failure due to liquefaction and landslide and surface fault rupture and tsunami. Ground motion is quantified in terms of peak ground acceleration (PGA) and spectral acceleration (SA), and ground failure is quantified in terms of permanent ground displacement (PGD). For computational and efficiency and accuracy, earthquake losses are generally computed using location specific values of ground shaking are interpolated between PGA, PGV and spectral acceleration contours respectively.

PGA: The peak ground acceleration is the maximum acceleration experienced by a particle location of the places due to course of the earthquake motion. Thus, it is a level of ground motion severity experienced at site due to an earthquake (Georisk, 2004).

SA: It refers what is experienced by any type of infrastructures services as modeled by a particle on a mass less vertical rod having the same natural period of vibration as the building. The unit of spectral acceleration is g (gravity)

Spectral Velocity: It is defined as deprivation of the displacement record with respect to time.

Spectral Displacement: The spectral displacement (SD) is illustrated as displacement of a modeled particle on a certain damping mass-less rod, which is driven on its base by the seismic record.

3.8.2 Lifeline Inventory

Development of inventory for all lifelines was a major task. Different types of specified lifelines have been inventoried in terms of its points or line. Examples of points are telephone cabinet, reservoir tanks, electric transformer; hospital etc. lines would be sections of road, sections of pipeline, electric transmission line. Points and lines have been introduced in some lifeline to provide better location information on the path of lifeline.

The inventory data have been compiled into an electronic database, which generally consists of digitized location and type of facility for single site lifeline facilities. And limited information on facility attributed for network lifelines.

The specific lifelines that have been inventoried for Ilam municipality are,

- Road Transportation
- Telecommunication
- Electricity system
- Water Supply system
- Petrol pump
- Essential Facilities (School, Hospital)

3.8.3 Direct Physical Damage

To identify physical damage of infrastructures, damage functions and fragility curves are used in this method. Fragility curves describe the destruction excess probability with respect to the earthquake physical parameters (HAZUZ99, 1999). Damage functions or fragility curves or vulnerability curves for each facility are modeled as log normally distributed functions that give the probability of reaching or exceeding different damage states for a given level of ground motion or ground failure and an associated dispersion factor (Lognormal standard deviation).

To develop fragility curve for an area, every type of services are classified to different groups according to their structural system, seismic design code. A fragility curve has been developed for each group.

The HAZUS model uses the various classifications of civil structures as well as infrastructure for assessing earthquake losses. The up to date building inventory is always necessary to assess the loss for pre and post earthquake events. The method of making building inventories is well described in this model. There is a need to study the criteria of building classification and building inventory used in this model for assessing risk for buildings under Indian conditions. The database alone cannot solve the problem of making a good inventory of buildings and infrastructure needed for loss estimation. There is need to classify this database according to the different classes and parameters that are typical for the Indian conditions. The classification is necessary to reduce the calculation for estimating losses.

HAZUS have been partially tested using actual inventories of structures plus correct soil maps; it has performed reasonably well (FEMA, 1999).

3.8.4 HAZUS Used In the Present Context

In these models, different data such as the earthquake magnitude soil type and geological characteristics of the ground between the center and structures, structural characteristics of the any type of services are used. And, attenuation relationships and fragility curves are two basic concepts/ models that are used for estimating damage level of lifeline structures in case of an earthquake. As most of these data have spatial component and location, GIS is a proper tool for their integration and analysis to get the result.

To estimate destruction for an individual service, firstly, the earthquake magnitude at the location of services should be calculated by use of an attenuation relationship in term of PGA, PGV or PGD. In the second step, by the use of services properties, respective fragility curve should be identified and then by use of that curve the probability of excess of destruction from a predefined percentage should be obtained.

The hazard parameter used in this method is PGA, so this method requires technical data, liquefaction level of soil, and slope status of area. However this method seems more reliable and logical. It shows geographical location of damaged point or line.

CHAPTER IV

INTRODUCTION OF THE STUDY AREA

4.1 Geographical Location and Area

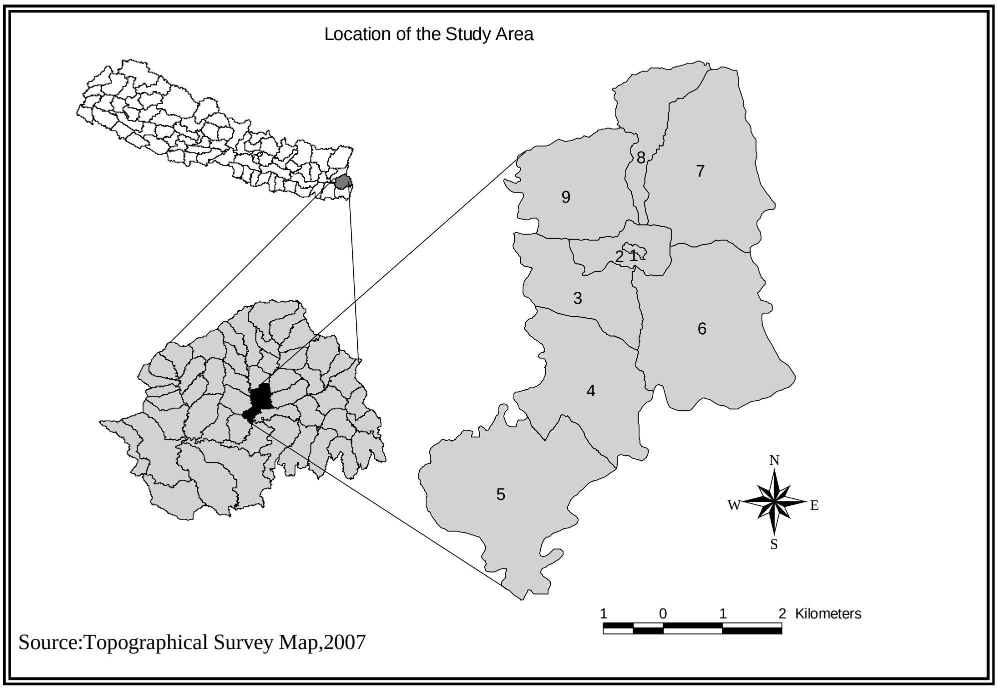
Ilam municipality is the headquarter of both Mechi zone and Ilam district. This municipality was established in the year 2015 B.S. It is situated in between 401m to 1407m altitude from the mean sea level. Geographically, this municipality lies in 26^0 56' 46" N latitude to 87^0 56' 46" E longitude. There are Maikhola in the east, Puwakhola in the west, Barbote VDC in the north and Maikhola and Puwakhola in south of this municipality. The total area of this municipality is 27.0 sq km. About 2.7 sq km of the total area has been occupied with urban area.

There are various legends of being its name ‘Ilam’. Some believe that Limbus and Lepchas had ruled this area in ancient time, especially Lepcha in the east of Maikhola and limbu in the west of it. There was vast population of Putka and the name of Putka in their language is called Ilam. So, they recalled it “Ilam”. Another group believes that the word “Ilam” is derived from Limbu caste. By the word Ilam, ‘I’ means “twist” and ‘lam’ means “roadway”. Therefore, peoples called this place Ilam.

Ilam municipality, the headquarter of Ilam district is hailed as the “queen of hill” due to cool environment and paranoiac of this municipality. It has been considered as “beautiful” place for internal and external tourists as it is attractive. Historical tea garden , various temples like Seti Devi, Narayansthan, Maisthan, Gumpadanda and other religious places have added extra energy in tourism of Ilam. Its natural beauty too has made it as a major center for tourist in the east of Nepal.

Ilam municipality is also rich in social and physical infrastructure, which has contributed a lot in the rise of its GDP production. The major economic source of this municipality is agriculture. Agriculture productions like cash crop, tea, alichi etc; are based on industry and tourism. Therefore, agriculture has become the strongest pillar for the economic development of Ilam municipality. Deforestation and overgrazing to meet the needs of growing population lead to desertification**.** Earthquakes are the most destructive in these regions due to poor building construction and high seismic vulnerability of construction. Location of the study area has been shown in the Map 4.1.

Map 4.1 Geographical Location of the Study Area



4.2 Susceptibility of Earthquakes

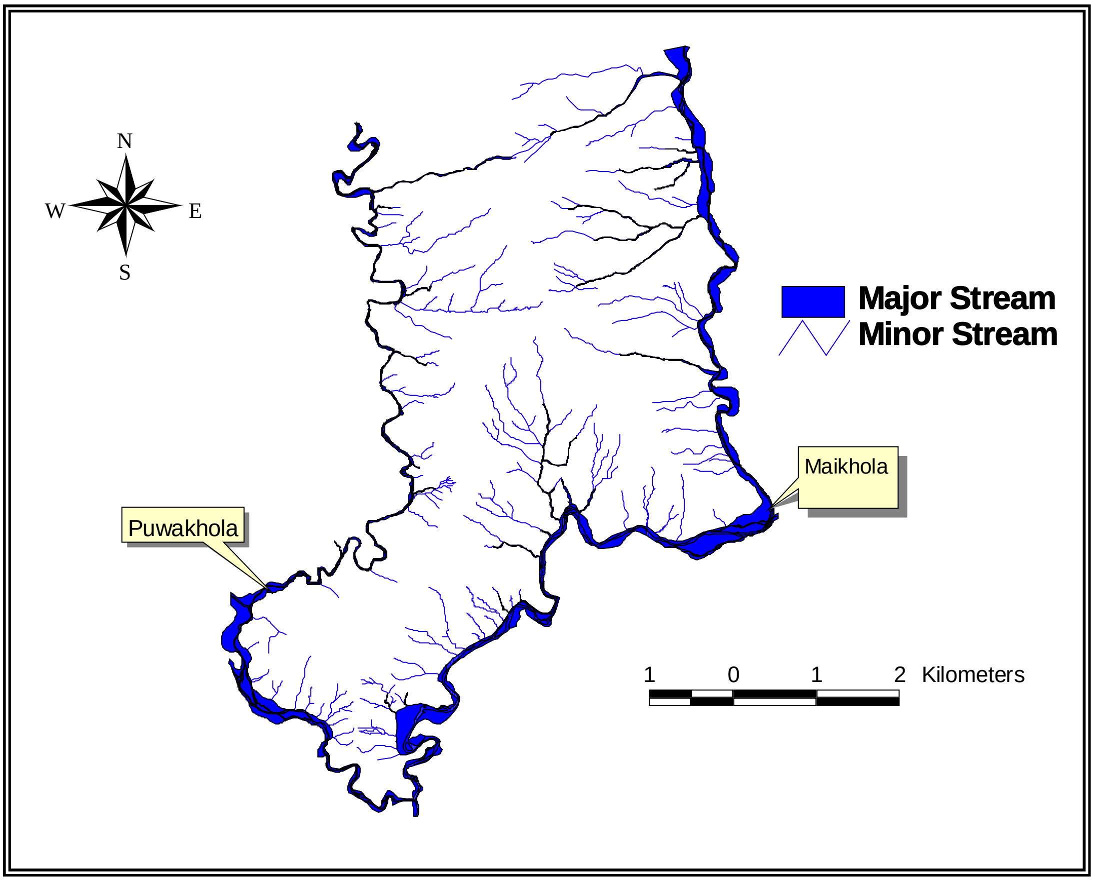
Ilam municipality is situated in the foothills of the Himalayas which is highly susceptible to earthquakes, thus it has the greatest potentiality for a future great earthquake(M >7.5)at any time (Sharma, 1998).

The areas that have harsh climatic conditions, are subject to extreme weather, or that have unstable geology, are difficult to develop, and development gains can be fragile and easily overwhelmed by the effects of natural events. The soil of the city is abundantly stony loam, and some areas have sandy type of soil. It is pertinent to note that non-engineered structures on sandy soil are more susceptible to collapse or damage during an earthquake. On the other hand, lack of development itself contributes to disaster impacts. The quality of construction is often low. Land registration processes, and other regulatory mechanisms are lacking.

4.3 Drainage Pattern

Drainage pattern is an excellent indicator of not only the suffice lithology and the geological structures, rather, it is the ongoing morphmetric process of the earth. Since the country is filled by various streams and river system, Maikhola and Puwakhola lies in the Ilam municipality. Map 4.3 shows different type of drainage pattern in Ilam Municipality.

Map 4.3: Drainage Pattern in Ilam Municipality

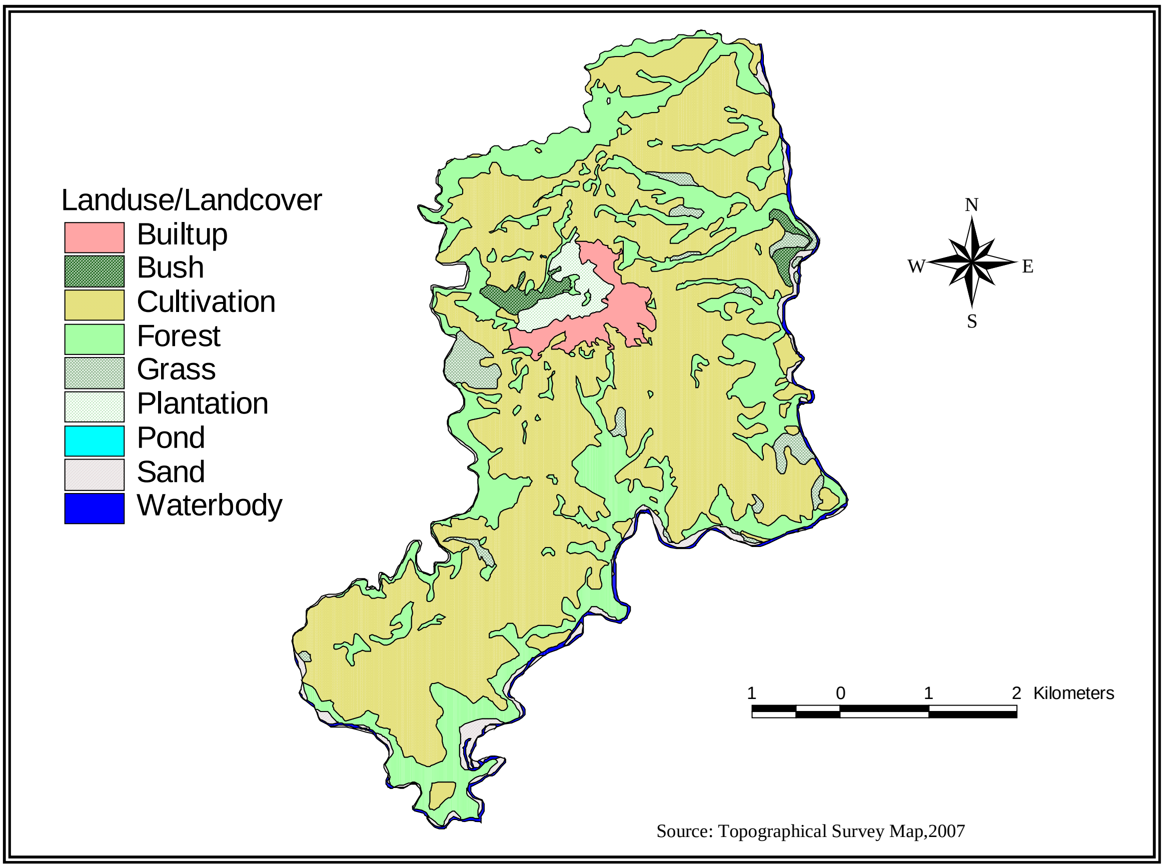


Source: Topographical Survey Map, 2007

4.4 Land use/Land Cover Pattern in Ilam Municipality

Land use/ Land cover pattern of the area produced a multidisciplinary survey of natural and man made features. It is important for improved planning and long-term development and utilization of the land. For example, where should a road be built? Where should a utilized area? Which will serve an area effectively? Land use/ Land cover pattern can be visualized in Map 4.4.

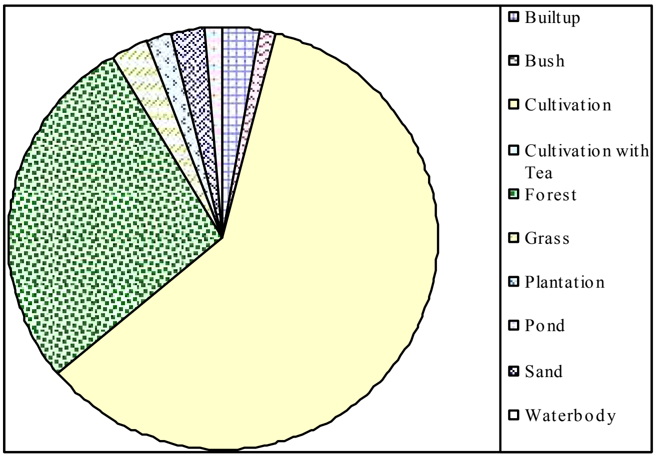
Map 4.4: Land use /Land cover in Ilam Municipality



Map 4.4 shows that the land use pattern of the area is diverse. Different types of land use have been classified into forest, cultivated land, tea state, and shrub land and settlement area. In the study area, conversion of forest land to cultivated land is being accelerated due to population growth. About 60 % land is cultivated land.

Cultivated land is extensively distributed in the western part of the study area. Other parts of the area and rocky terrain are covered by forest and shrub land.

Chart 4.4 Land use/ Land Cover Pattern of the Area



Land use Type	AREA(Sq Km)	Percent (%)
Built-up	0.7318	2.73
Bush	0.3169	1.18
Cultivation	16.0275	60
Forest	7.3848	27.62
Grass	0.7434	2.78
Plantation	0.4582	1.71
Sand	0.6823	2.55
Water body	0.3873	1.444
Total	26.7354	100

Source: Derived From Land use/Land cover Map 4.4

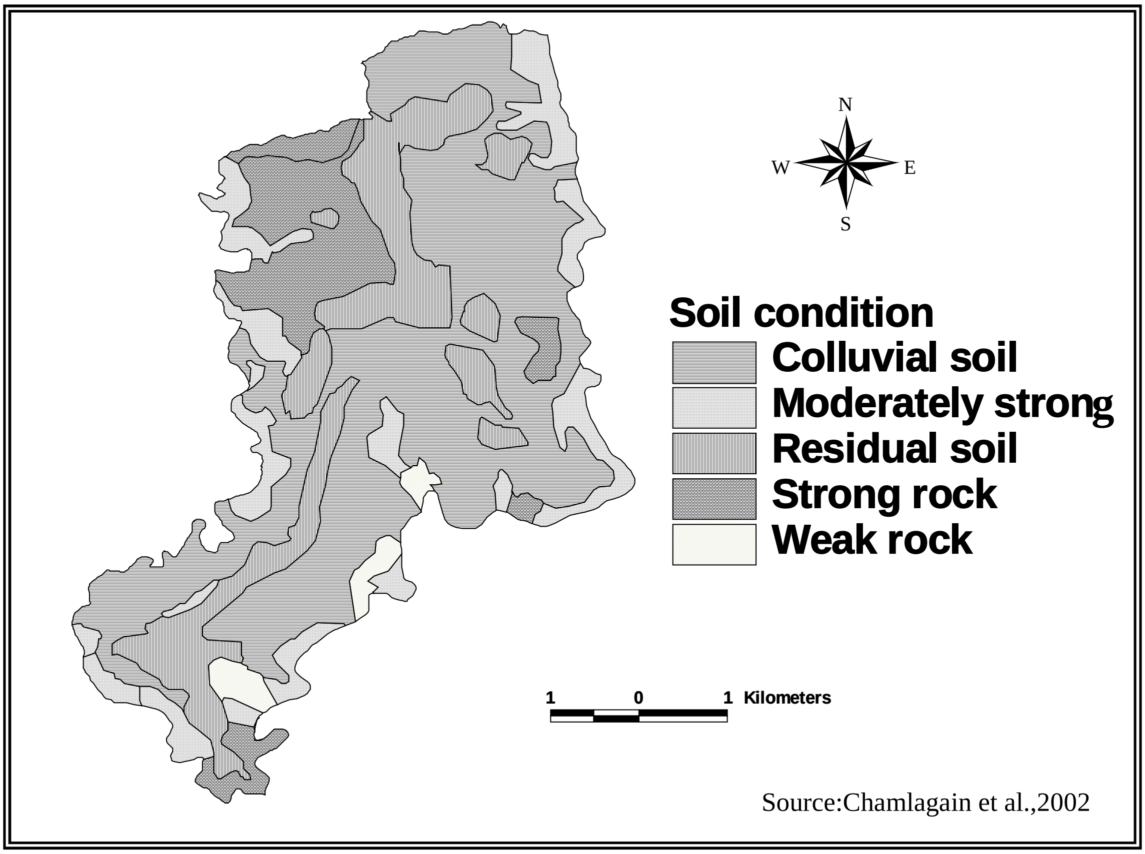
4.5 Climatic Conditions

This municipality is also an apt from the viewpoint of climate. Its climate is subtropical. However, climate varies according to geographical diversity as it has been stretched from very low area to the high area. There is hot climate in basin side and warm climate in market center. The temperature ranges from $27^{0\ c}$ in lower area and 5^{0c} in market area. The average rainfall of this area is 250mm.

4.6 Soil Condition

Soil is an important aspect of terrain analysis. The spatial distribution of the soil are not evenly distributed in the area. Colluvial soils are predominant type of soils in the area. Soils of the study area are classified according to their origins, i.e. alluvial, colluvial and residual soil etc. Map 4.6 shows different types of soils of the study area.

Map 4.6: Soil Type in Ilam Municipality



Source:Chamlagain et al.,2002

4.7 Geological Setting

Illam municipality lies in the southern part of the higher Himalayan where the higher Himalayan crystalline have been thrust over the lesser Himalayan metasediments along the main crustal thrust (LRMP, 1986). The area is mainly controlled by tectonic process. Rugged hills, numerous deep gorges are the main features of the area. The study area is a part of the basal and middle portion of the Mahabharata crystalline, which is divisible into two subunits (Chamlagain et. al, 2002). Unit 1 consist of garnet-kyanite, sillimanite genesis and gray quartzite, whereas unit 2 is characterized by the presence of garnet Kyanite Sillimanite genesis, orthogenesis and white colored, course grained, fractured quartzite. Geological setting of the area can be seen in Map 4.7 and Table 4.7.

Map 4.7: Geological Setting of the Study Area

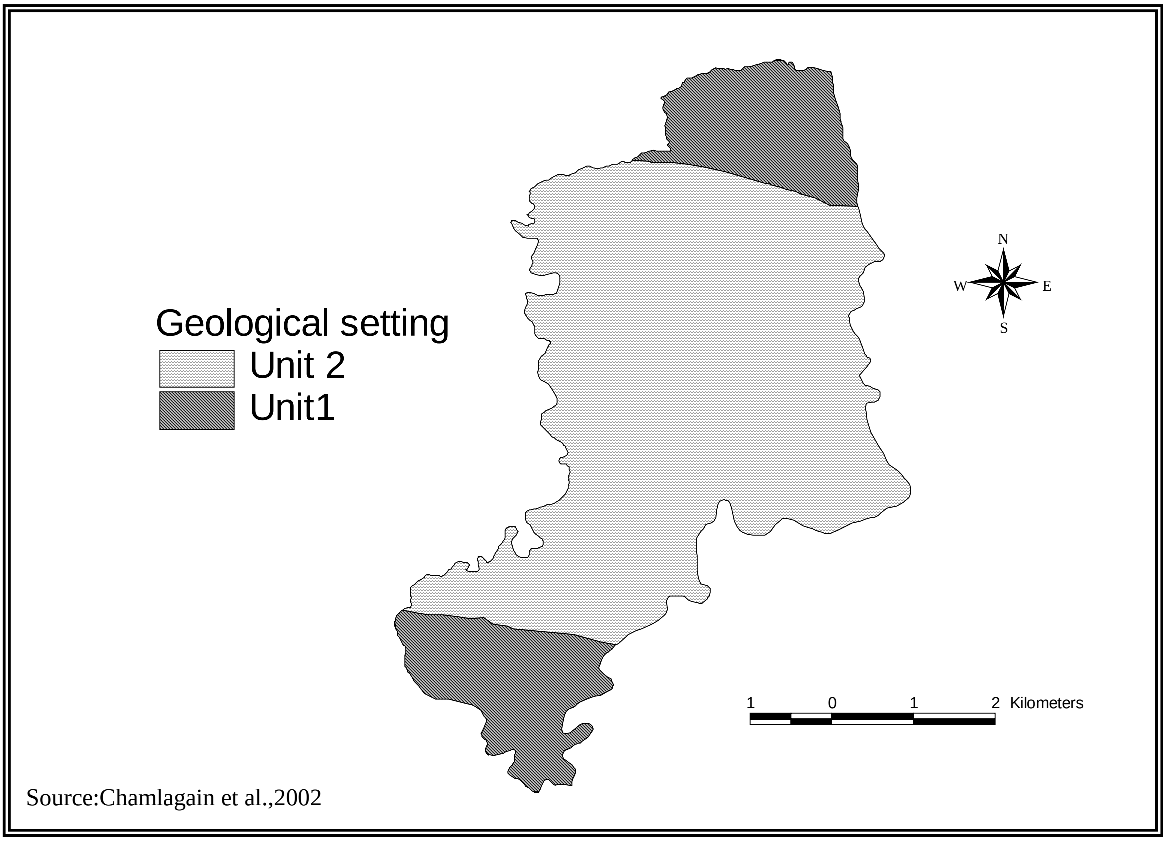


Table 4.7: Geologic and Ground Condition Units

Units of Geologic Map	Ground Condition Unit	Relative Intensity
Unit1	Garnet-kyanite, sillimanite gnesis and gray quartzite	VII
Unit2	garnet kyanite sillimanite gnesis, orthogenesis and white colored, course grained, fractured quartzite	VIII

Maps 4.7 indicate that Geology of the area is dominated by the Precambrian to Cambrian Kyanite and sillimanite bearing genesis, biotype schist, Metaquartizite, amphibolites, cal silicate genesis, orthogenesis and angiogenesis. The Mahabharata

crystalline of the eastern Nepal are apparently continuous with the Darjeeling genesis of the Sikkim Himalayan (Chamlagain et. al, 2002).

Available geological information indicates that great earthquakes with magnitudes in excess of 8.0 have occurred on the area. In addition, extensive but more moderated seismicity has been associated with the same seduction zone.

Almost all of the areas pass directly through the fault areas. The fault is believed capable of producing earthquakes as large as magnitude 8.0. A large earthquake on the fault is of potentially catastrophic proportions.

4.8 Population Distribution and Size

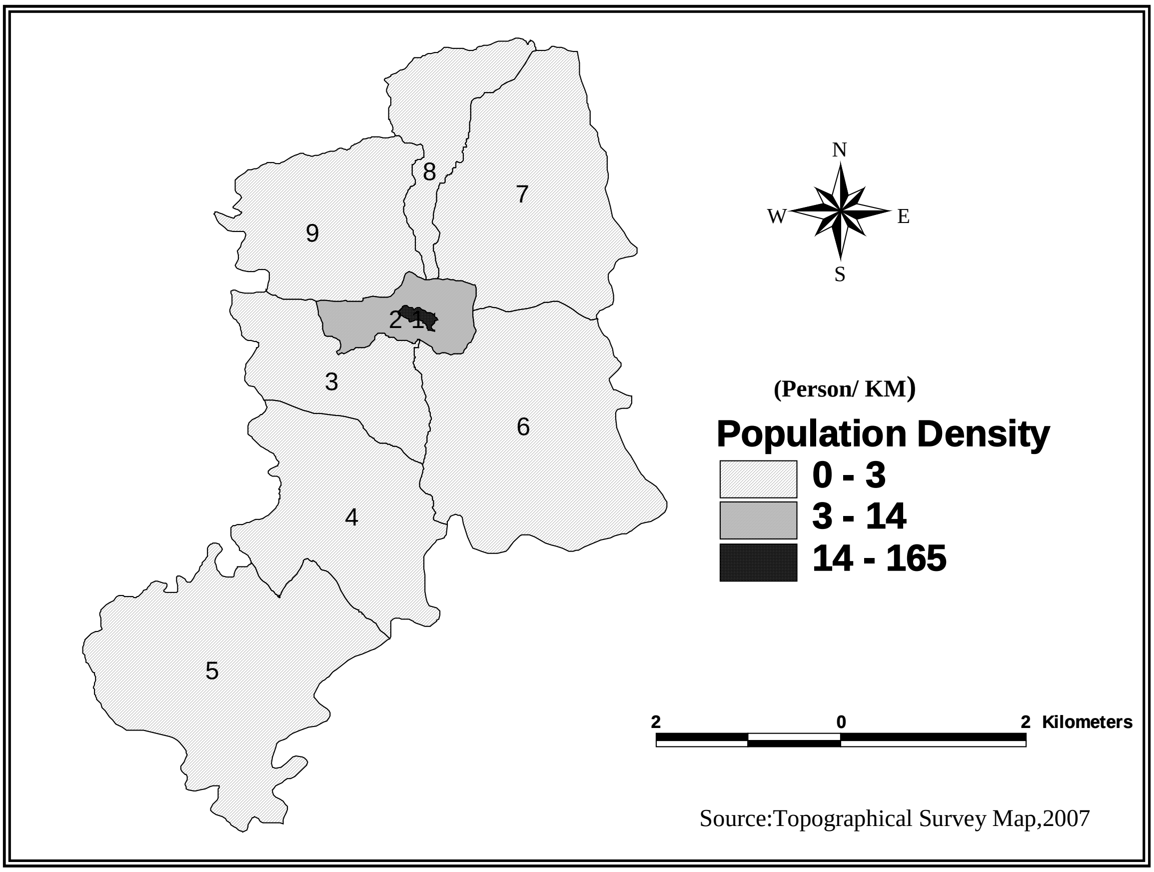
There are 16,246 families living in 3,311 houses in the municipality. Among total population 7,899 are female and 8,337 are male. This municipality contains 84.6% Hindu, 12.8% Buddhist, and Kirat 2.0% and others 0.6%. On the basis of ward, total population has been shown in table 4.8.

Table 4.8: Population Distribution Pattern in Ilam Municipality

Ward No	Population(2058)			No. of HH
	Male	Female	Total	
1	502	462	964	159
2	1995	1789	3784	643
3	1062	971	2033	383
4	649	660	1309	307
5	780	769	1549	359
6	1104	1044	2148	459
7	627	620	1247	249
8	660	694	1464	329
9	848	890	1738	423
Total	8337	7899	16246	3311

Source: Ilam municipality, 2007, November

Map 4.8: Population Density in Ilam Municipality



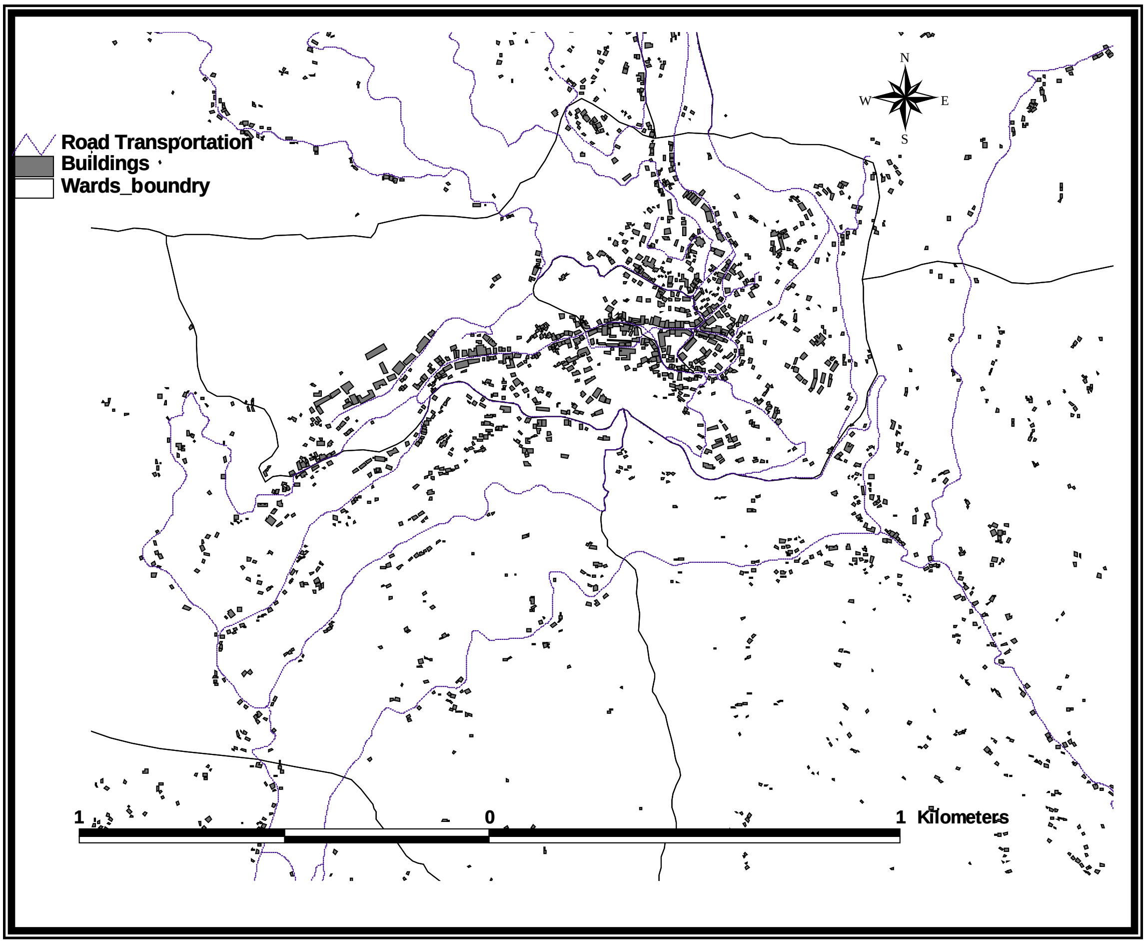
Map 4.8 indicate that population density in Ilam municipality is irregular. In map it can be clearly seen that only ward no 1 has higher population density 165 person per km. and other ward have very low population density.

4.9 Urban Form and Settlement Pattern

The distribution of settlement pattern in Ilam municipality is irregular. Several cluster of houses are seen in market particularly in 1 and 2 ward. 5-15 houses are attached with each other. The built up density gets higher. Moving outside the market there is lot of agricultural and vacant land. There, the built up density is low. Buildings in the market area have multifunctional use. There are commercial and residential areas. Ground floors are used for shops and upper floors for living. Each cluster of house exists at distance of few meters and is connected by highway, major trail or footpath. From the motorbike road the settlement is connected by major trail with gravel, earthen or stone paved .The average height of the building in this area is 3 to 4 floors (about 8m), meanwhile, the average width of the road in these areas is only 3 m. Other types of structures like electric line is also located closely to the road.

On the basis of the above mentioned analysis, the roads in the market area are blocked by collapsed buildings in an earthquake for two reasons; narrow width and dense built-up along the road. These areas need to be seriously taken into consideration in the earthquake emergency. Settlement pattern of this area is shown in Map 4.9.

Map 4.9 Urban Form and Settlement Pattern



CHAPTER V

LIFELINE SERVICES IN ILAM MUNICIPALITY

The country has been defined as underdeveloped regions, in terms of relative scarcity of basic infrastructures and facilities such as road, bridge, drinking water, irrigation, electric power and income generating activities (MLD, 2000). By virtue of diverse relief features, there is a great disparity in different regions of the country. Regional or local sectors suffer from inadequacy of development activities. Industrial development is extremely limited due to poor infrastructure. On the other hand, existing structures of the Nepal are also lack of proper analysis of seismic design (Jaisi, 2002). They are partially or wholly unsafe due to improper design, construction, material etc. Buildings have been built without earthquakes resistant. Road transportation, water and sewerage pipes, electricity pipes and telecommunication are constructed according to local condition, and aggravated earthquake vulnerabilities. It is mainly because of the lack of awareness in the people and government regarding the important of structural analysis, quality control or good construction process. Therefore, due to a disaster especially in an earthquake will create great impact on population living in earthquake prone area. Such poor social structures will also get exposed to associated secondary hazard like fire, waterborne diseases, epidemics and technological accidents. All of these possible features contribute to higher vulnerability and risk of earthquake disaster.

Ilam municipality is rich in the development of physical and public infrastructure than the other VDC of Ilam. Most people of this municipality have been taking advantages from the facilities of this infrastructure like transport, electricity, drinking water and telecommunication etc. Several NGOs and INGO organizations are also helping for its development.

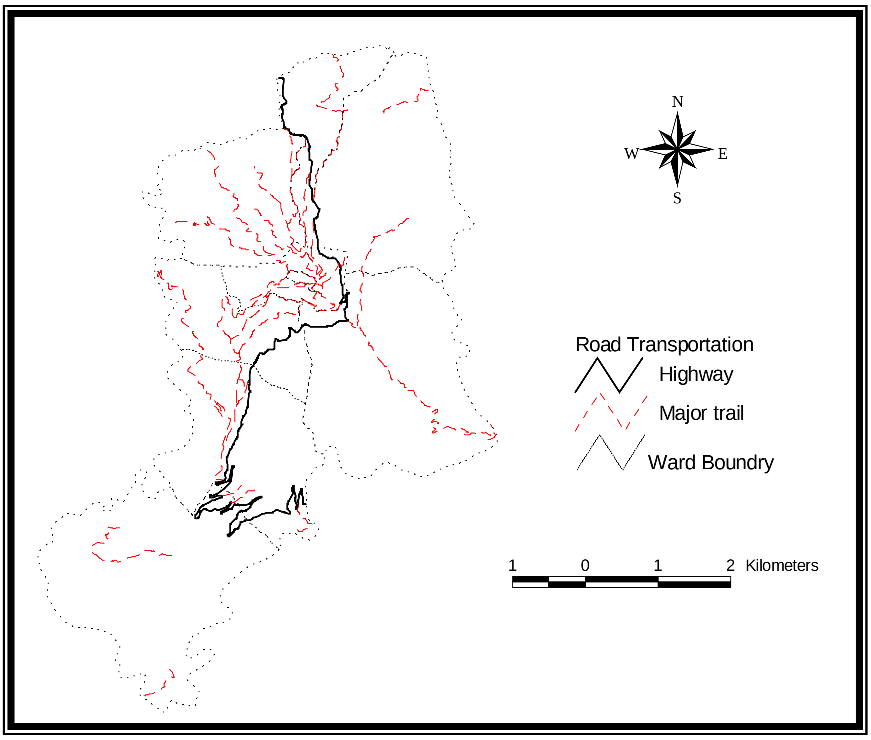
5.1 Existing Road Network in Ilam

Road Transportation includes urban and rural freeways. It can be divided into highway, major road, minor road, gravel road and foot trail etc. Road transportation also includes pavement, base and sub base (HAZUS99, 1999). Pavement types may be cement, concrete or asphalt concrete. Base and sub base materials include aggregate, cement treated aggregate and lime stabilized, and soil cement bases. Embankments may or may not include retaining walls.

Transportation, for human being, is necessary. It is needed for exporting and importing various essential things from one place to another place. The development of transportation contributes to develop the whole nation by strengthening the relationship between and among people, transporting goods and peoples from one place to another etc. Moreover, it helps to broaden the horizon of business trade from which the economy of the country gets pregnant. Means of transportation available in the present world are land transportation (Road, railway), water transportation and air transportation. In the context of Nepal, road and air transportation are prevalent.

Though, Ilam municipality is hilly area; it is rich in transportation because Mechi highway has passed through the municipality. Along with this, there is facility of gravel link roads in each wards of this municipality. The total length of roads within the municipality is approximately 58 km, which consists of black-topped, gravel, earthen and stone paved. In spite of these, there is difficulty for linking all of its area with the road. The construction of road needs too much capital and technology and, being a poor municipality, Ilam is unable to invest for it. Further more, the roads have not been repaired for a long time. Most of roads have already been destroyed. It takes too much expenditure. So, the condition of transportation in this area is poor. Moreover, there is still Goreto(trail)and, Ghodeto ways in the hilly area where people survive depending on their arm and backs. The type of road are clearly seen in the Map 5.1.

Map 5.1: Existing Road Network in Ilam

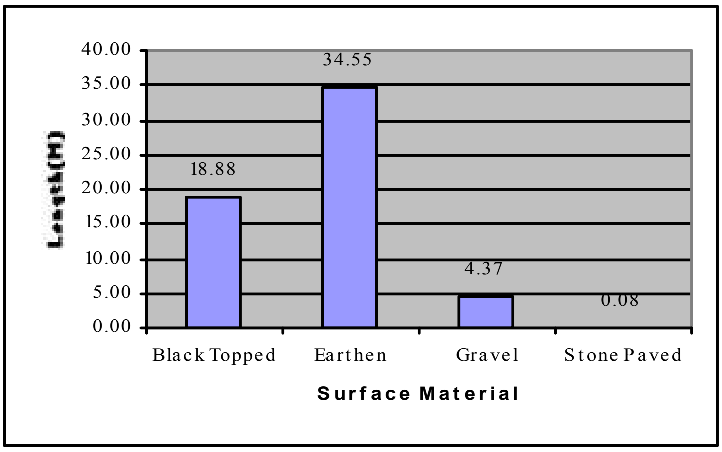


Source: Topographical Survey Map, 2007

The network of Ilam municipality consists of different categories. There are about 19 km length black-topped road, gravel road 12 km and earthen roads having 50 km in the municipality. Charts in figure and table also display the distribution of road length in Ilam Municipality

Surface Type	Length(Km)
Black Topped	18.88
Earthen	34.55
Gravel	4.37
Stone Paved	0.08
Total	57.88

Source: Derived form Map 5.1



In recent years, lack of improvement and management strategies have resulted into congestion, decrease in travel speed and capacity, as well as decrease in road safety.

Photo 5.1: Narrow Road with Both sides Built up

Source: Field Survey, 2007

5.2 Existing Drinking Water Supply Pipeline Network in Ilam Municipality

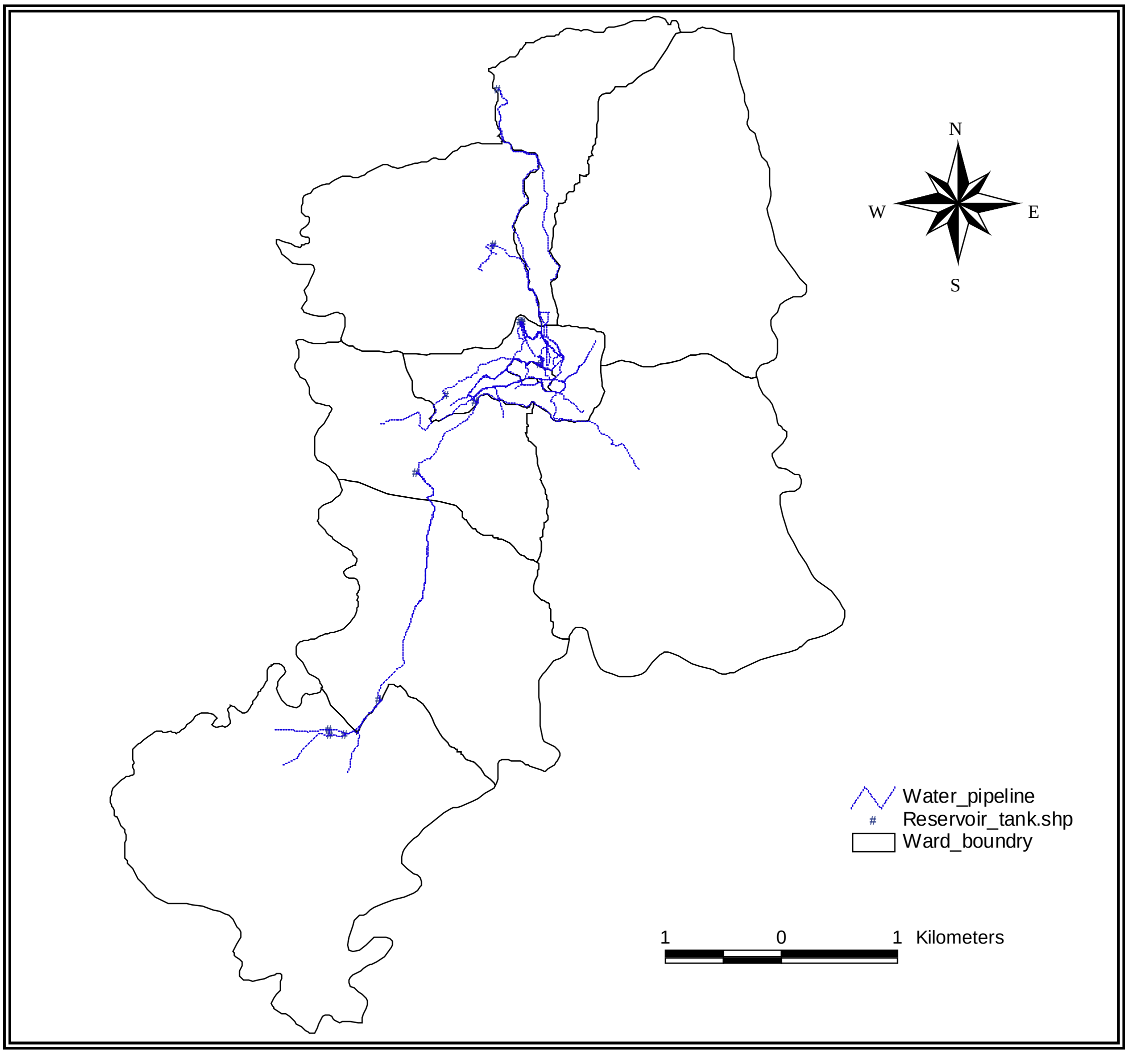
Water system consists of supply transmission and distribution components such as water reservoir tanks, pipeline network and resources. Water reservoirs tanks may be buried underground, or elevated storage tanks or impounding reservoirs. Underground storage tanks are typically reinforced of pre-tested concrete wall construction with either concrete or wood roofs. They may be circular or rectangular. On ground, water supply storage tanks are typically vertical anchored and/ or unanchored tanks supported at ground level. Construction materials include welded, bolted, or riveted steel, reinforce or priestesses concrete, or wood. Tank foundations may consist of tanks supported by single or multiple columns. Most elevated tanks are steel and or generally cylindrical or ellipsoidal in shape. Elevated tanks are more common in areas of flat terrain. There is large variation in tank sizes (height and diameter) so, volumes range from thousands to millions of gallons.

Pipelines may be underground, on ground or supported on elevated frames above ground. However, mostly pipelines in the water supply system are located underground. Pipe materials include cast-iron, welded steel, asbestos cement, and plastic. Typically, pipelines are 20 inches or more in diameter. These are usually welded steel or reinforced concrete and may carry water at high pressures. Joints in steel pipes may be welded or bell and spigot types. In addition to the pipe themselves, pipelines may require gate valves, drains, surge control equipment, expansion joints, insulation joints, and manholes. Check valves are normally located on the upstream side of pumping equipment and at the beginning of each rise in the pipeline to prevent back flow. Gate valves are used to permit portions of pipe or check valves to be isolated.

Ilam municipality has conducted various drinking water projects. However, these have been unable to supply drinking water due to overpopulation. The water supply from Bhandikhola of Maipokhari and Gitangkhola of Manmaiju VDC has become insufficient for the people of markets of this municipality. JAICA, in 2048 B.S., had helped this municipality for the provision of drinking water, but after that it has done nothing. Nowadays, the demand of water in Ilam municipality has been 25 liter per second but the supply has been only 14 liter per second.

In 2064/2/30, the flood in Gitang khola has destroyed the structure of origin of water by swaying the catchments, reservoir and 600 meter pipe of Gitang Muhan. For its repairment it may takes about 6 lakh rupees (Ilam municipality Staff, 2007). Distribution of pipeline network can be easily seen in Map 5.2.

Map 5.2: Water Supply Network in Ilam Municipality



Source: Ilam Municipality Water Supply Division, 2007

Map 5.2 shows pipeline network and water reservoir tanks in Ilam. In the map it can be seen that there is limited pipeline network and reservoir tank . Only certain population are using drinking water facility. Total number of tank and pipeline length has been tabulated in Table 5.2a and 5.2b.

Table 5.2a: Water Tank in Ilam

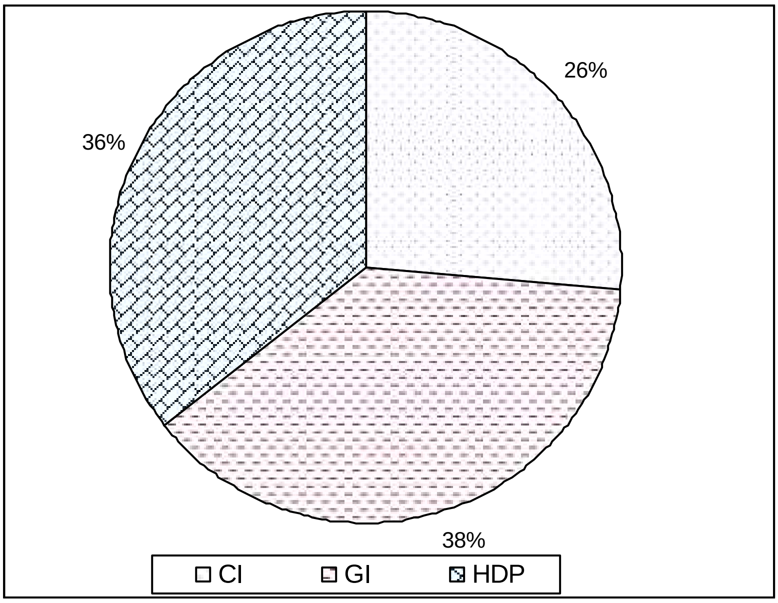
Tank Type	Total Number
Fabric Glass	2
Masonry	3
RCC	9
Total	14

Table 5.2b: Pipeline Distribution in Ilam

Material	Total Length(M)	Percent (%)
HDP	11881.5058	35.58
CI	8803.4014	26.36
GI	12707.5890	38.05
Total	33392.4962	100

Source: Ilam Municipality Water Supply Division , 2007

Charts 5.2 Pipeline Distribution in Ilam



Charts in 5.2 display the pipeline distribution in Ilam Municipality. The pipeline network of the Ilam Municipality consists of different categories of pipe material. It includes HDP, GI and CI type of Pipes. HDP pipe are main dominant pipe in Ilam.

Photo 5.2: Pipeline in Ilam Municipality

Source: Field Survey, 2007

The water system forms are shown in tables 5.2 and figures 5.2. They refer to the parameters to be analyzed to understand the water system, expected behaviors during emergency operations and in the reconstruction phase.

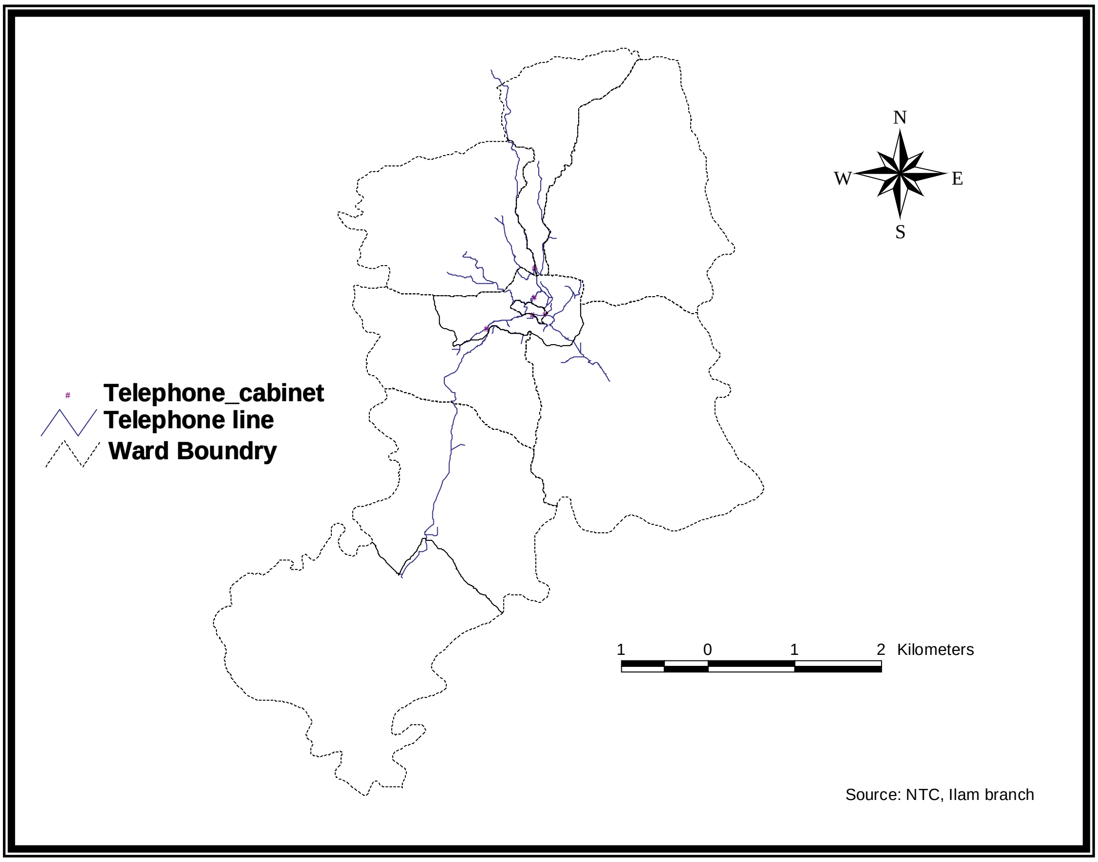
5.3 Existing Telephone Distribution Network in Ilam Municipality.

Telephone service, an effective media for communication, is increasing rapidly in this area. So far about 14-15 hundreds telephone services have been distributed in this area. Each ward has facility of telephone service. However, it is not sufficient yet in the ratio of users. Until 2007/10/15, it has distributed 846 lines telephone in the municipality. Still, it seems to extend the telephone service in rural area.

Along with telephone, other media of communication- email, internet, and fax are available in this municipality. Two weekly newspapers, local newspapers in the municipality have made easier for information. Transportation has made easy access for the availability of means of communication. 8-10 private information centers have been established.

Post service plays critical role for communication especially in rural areas. There is a district post office in Ilam municipality. Post boxes for its effectiveness have been kept in various places of municipality. Most people of municipality are benefited by post boxes. Telephone network can be seen in the Map 5.3.

Map 5.3: Telecommunication System in Ilam Municipality



Map 5.3 shows distribution of telephone network in Ilam Municipality. It means, limited number of have been using telephone facilities.

Table 5.3: Telecommunication System in Ilam

Cabinet Location	Type	Length(M)
Shanti Chowk	Distribution Line	2796.7862
Birendra Chowk	Distribution Line	723.1429
Ratna Chowk	Distribution Line	5824.5757
Pipal Chowk	Distribution Line	4472.1029
Near NTC	Distribution Line	4507.38
Telephone Tower	Main Line	1549.8547
Total		19873.8424

Source: Derived from Map 5.3

Map 5.3 and Table 5.3 show that Ilam Municipality has limited telephone services. It consist 6 telephone cabinets in different places of the area. The capacity of cabinet also varies. Out of total length, main line covers 1549.85 m.

5.4 Electric Network in Ilam Municipality

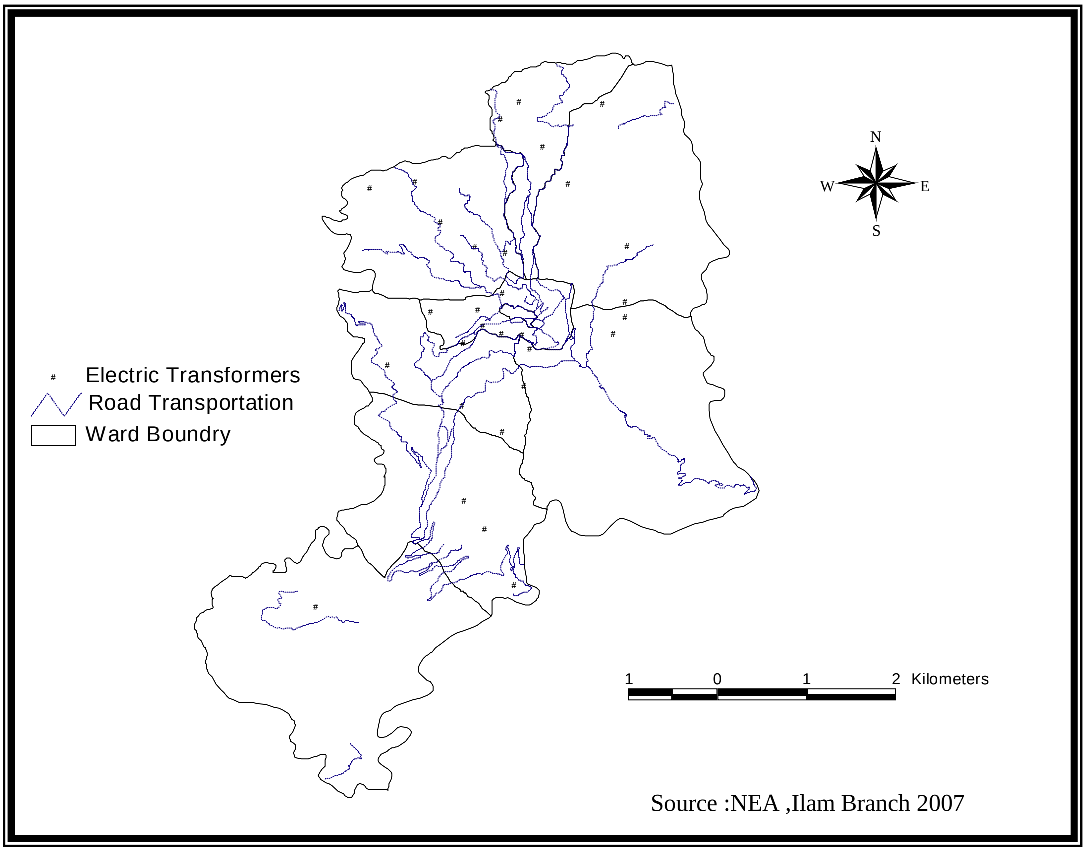
An electrical system consists of substation distribution circuits, generation plants, transmission lines and associated equipment including electric pole, and a substation with transformers and switching equipment. Electric transformers are frequently distributed on different area.

Transmission lines may be underground or above ground (supported by towers). Towers are usually steel, wood and iron which carry several circuits out at high voltage. Each circuit consists of three conductors, one for each phase. Towers are provided with reinforced concrete footings and may be supported on piles. Most transmission systems are AC, but some long distance lines are DC. The DC systems require converter stations at each end of the line.

Transmission substations in the electrical system generally receive power at high voltages (220Kv or more) and step it down to lower voltages for distribution. The substation consist one or more control buildings, towers, conductors, ground wires, underground cables, and extensive electrical equipments including banks of circuit breakers, switches, wave traps, buses, capacitors, voltage regulators, and massive transformers. Circuit breakers protect transformers against power surges due to short circuits.

Distribution lines may be underground or above ground supported by towers or poles. Towers are usually steel and poles are usually iron ands wood. Poles are provided with footings or may be embedded directly into the ground. Distribution lines typically operate at lower voltages (64 KV or less). The whole network of electricity can be seen in the Map 5.4.

Map 5.4: Electric Network in Ilam Municipality



Map 5.4 shows the distribution of electric transformers in the area of Ilam Municipality. Transformers are sparsely distributed in the area. It means earthquake produces scattered but wide spread damage.

Photo 5.4: Electric Network in Ilam Bazar

Source: Field Survey, 2007

5.5 Essential Facilities

Facilities that provide services to the community and those that should be functional following an earthquake are considered to be essential services. Essential facilities include hospitals, police stations, fire stations and schools. The probability of damage of essential facilities is determined on the basis of ground motion.

The essential facilities are classified on the building structure type and occupancy class.

5.5.1 Health Service Centre (Hospital)

Hospital is an important for human society. Hospitals are typically housed in one or more buildings. These are classified on the basis of the number of beds. Construction type varies significantly. The structural and nonstructural systems of a hospital are related to the size of a hospital. Smaller hospitals may contain only limited equipments associated with building services but large hospitals may contain water treatment equipment, emergency power diesels, chillers and boilers as well as sophisticated equipment used for treating patients.

After a bad earthquake critical medical facilities such as hospitals and ambulance services will be stretched to their limits. Some buildings might even be damaged and the injured and patients alike will have to be treated outdoors in open area. During times like this, most medical services follow a triage system. This basically enables them to focus their efforts and existent supplies on those who require assistance very urgently.

Being hilly area, Ilam municipality is in lower stage from the view point of health. Especially, people of rural area have not got proper treatment as there is not facility of health center, health post, clinic etc. There is a district hospital having 25 beds and Megh Bahadur Parajuli hospital having 6 beds which are providing health facilities to their public. There are only 4 ambulance services in Ilam municipality which are conducted by district hospital, Nepal Ex-army, Parajuli Hosptal and Nepal Red Cross Society.

Table 5.5.1: Health Service Center in Ilam Municipality

Type	No of bed	Remarks
Ilam Hospital	25	-
Dr Megh bahadur Parajuli Hospital	7	-
T.B.Clinic	-	Conducted by Ilam Hospital
Family Planning Clinic	-	Conducted by Nepal family planning
Merry Stops Clinic	-	Conducted by Marry stops
Khop Centers	-	Per month Janaswsthya Khop Kendra Ilam 2, Bhanjyang khop Kendra Ilam 5, Chureghanti Khop Kendra Ilam 8

Source: Ilam Municipality, 2007

To wrap up, in Ilam municipality, there is very small number of health center in the ratio of population. Therefore, it seems that there is necessity of hospital and clinic for the better health of the people in Ilam municipality.

5.5.2 Educational Center

Public schools in Nepal are the center of social and cultural life in rural and urban areas. Hence, there is greater chance of propagating earthquake awareness from school to the families and from families to the communities.

Public school buildings can serve as emergency shelters. Usually they have open grounds that could be used for establishing tents for shelter or field hospitals following an earthquake.

Usually, children going to the public schools are from middle to low income group. These are also the highly vulnerable group of the society.

Schools play a crucial role after an earthquake in helping a community to get back on its feet. Since schools are typically distributed throughout neighbors, they are an ideal location for homeless shelters, medical clinics, and other emergency functions. Functioning schools provide a feeling of normality to a community, helping people get back on their feet after a disaster.

Public schools, in Nepal, have been built up without trained masonry. Both their buildings and their occupants, face extreme risk from the earthquakes. This is, because of the fact that six thousand schools were destroyed in 1988 Udayapur earthquake (Dixit et al., 2002). Management of the public schools is largely depend on the responsibility of the local community. Usually very low budget is available with the school management system.

Mountainous municipality Ilam is rich in educational institution than other VDCs of Ilam district. Several primary schools, secondary schools as well as Mahendra Ratna Multiple campus are situated at the heart of this municipality.

Photo 5.5.2: Educational Center in Ilam

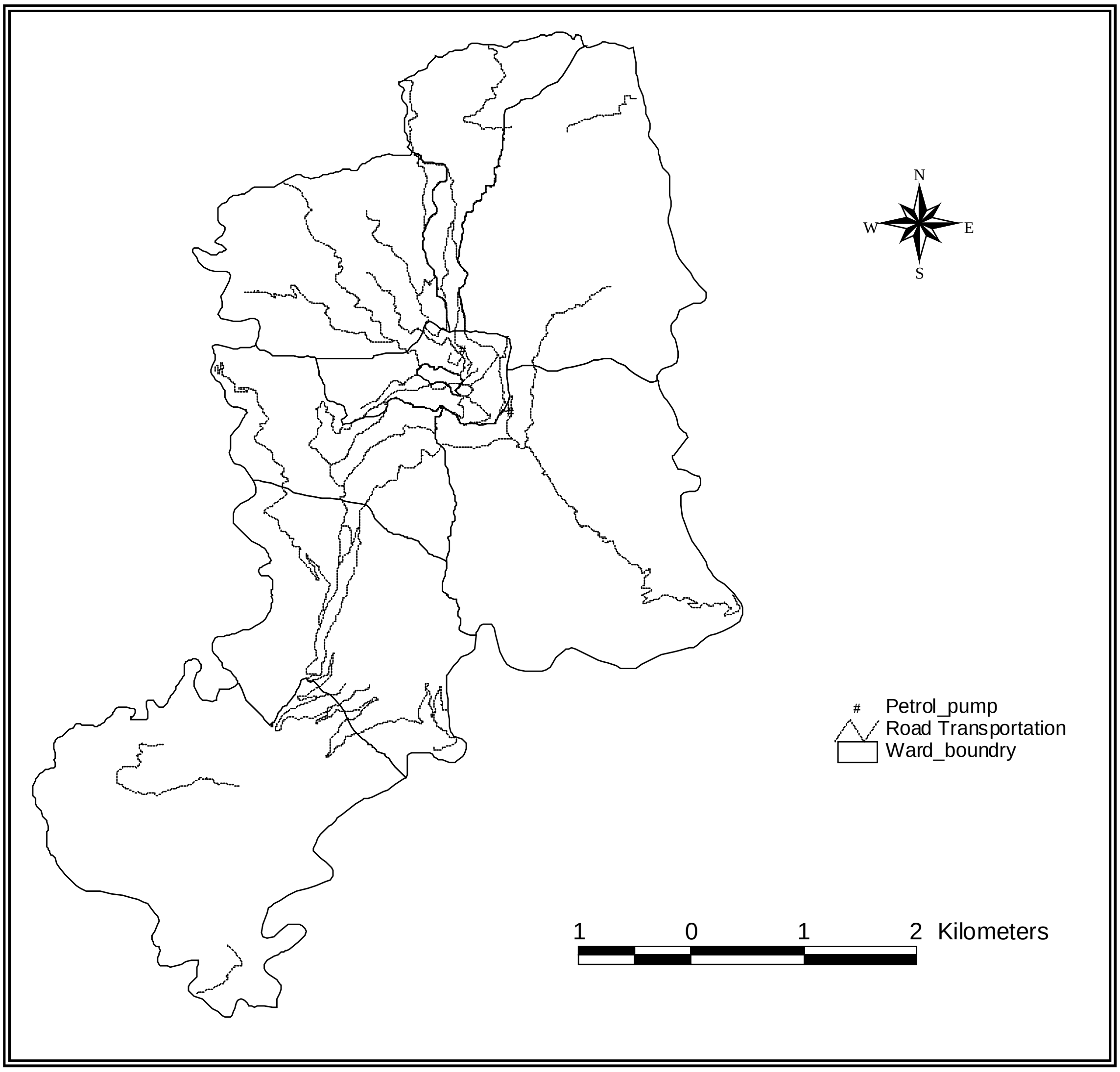
Source: Field Survey, 2007

5.6 Petrol Pump

Earthquake can rupture petrol pump and induce secondary type of hazards such as fire. Most petroleum materials (diesel, petrol, kerosene etc) storage tanks are unanchored, cylindrical tanks supported directly on the ground. Older tanks have both fixed and floating roofs, while more modern tanks are almost exclusively floating-roofed. Diameters range from approximately 40 feet to more than 250 feet. Tank height is nearly always less than the diameter. Construction material includes welded, bolted or riveted steel. Tank foundations may consist of sand or gravel, or a concrete ring wall supporting the shell.

There are only two petrol pump located in the municipality area which are shown in the Map 5.6.

Map 5.6: Petrol Pump in Ilam Municipality



CHAPTER VI

SEISMIC HAZARDS IN ILAM MUNICIPALITY

Nepal has three distinct physiographical regions- Hill, Mountain and Terai. It is located between Tibetan and Indian plates. Each of these regions has different rock, age, metamorphism, structures and geological condition (LRMP, 1986). The elevation rises with nearly 46 meters at every kilometer from north to south width of 193 km. In the past, several medium to large size earthquakes have devastating effect in different parts of the country with localized effect. Huge damage in lifeline services and causalities has occurred due to these events. Scientists have pointed out that plates are moving towards each other at 3 cm per year. It indicates that Nepal is threatened by a strong earthquake which will bring large damages and casualties to the city. So, disaster management community should prepare itself for responding to such Huge disaster.

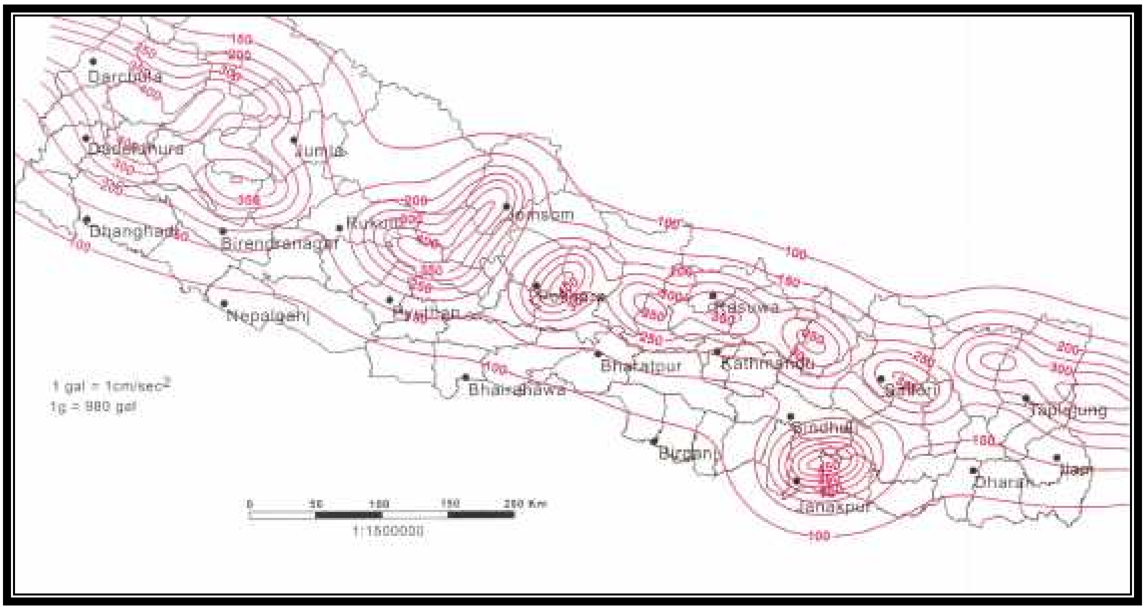
Earthquakes hazard include ground motion, ground failure (liquefaction, landslide) and tsunami/seiche. Fault rupture on the ground, produces local concentration of structural damage. A fault is a fracture in the crust of the earth along which blocks have moved on been displaced in relation to each other. Displacement can be either a horizontal or a vertical. Fault displacements produce forces so great that would damage to structures in areas close to ground traces of active faults. This hazard has different types of effects on lifeline services

6.1 Ground Shaking Hazard

Ground shaking hazard is associated with earthquakes. It produces scattered but widespread damage. It may be horizontal and vertical motions. Depending on soil conditions, it can be destructive at distances of even hundred kilometers. Ground shaking intensity caused by an earthquake depends upon on distance to the earthquake, the magnitude, and depth of hypocenter, geological condition and structure of soil between the hypocenter and the site and local soil and topographical condition. Ground shaking can be characterized by spectral response, peak ground acceleration and peak ground velocity.

In the study, the ground shaking demand is characterized by spectral contour maps developed by National seismic hazards maps of Nepal developed by Department of Mines and Geology. For a given magnitude, attenuation relationships are used to calculate to ground shaking demand for rock sites, which is then amplified by factors based on local soil conditions. PGA can be estimated on the basis of bed rock acceleration and soil amplification factor.

Map 6.1A: Seismic Hazard Map of Nepal



Source: Department of Mines and Geology, 2008

Above Map 6.1A shows that the peak ground acceleration in Ilam Municipality:

=150 gal (cm/sec^2) …….. (See Seismic Hazard Map of Nepal)

=150/980 g …………… (According to Newton's Low)

=0.153g

Amplification of ground shaking for local site condition is based on the site classes and soil amplification factors. In Table 6.1A, it has been defined Site classes based on local soil conditions of the area has been find out (for details see HAZUS 99, 1999)

Table 6.1A : Site Classes of on Soil and their Amplification Factor

Soil	Site class/Type	Amplification factor(F)
Residual soil	D	1.6
Colluvial soil	D	1.6
Weak rock	C	1.2
Moderately strong rock	B	1.0
Strong rock	A	0.8

Ground shaking of local conditions depend on amplifies rock for short period (0.3 second) and spectral acceleration. It can be expressed as equations,

$$PGA = PGA * F$$

PGA (i) is peak ground acceleration for site class i (in units of g)

PGA is peak ground acceleration for the sited geological condition (in units of g)

F is the short period amplification factor for site class i

For example,

For Strong rock (i)

Site class – A

Amplification factor- 0.8

Peak ground acceleration - 0.153

PGA (i) =PGA*F

=0.153*0.8

=0.122g

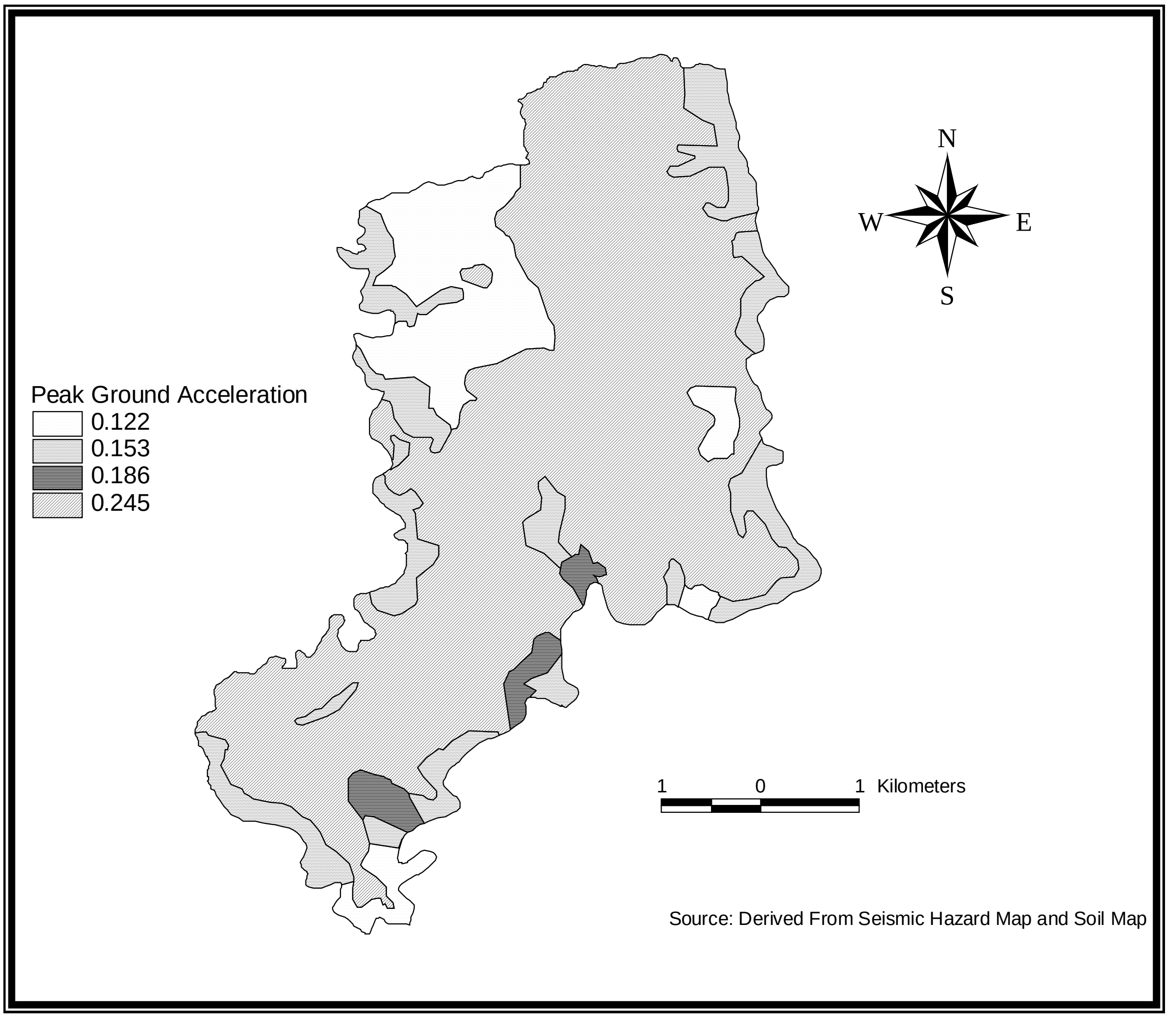
In the same way , it can be calculated peak ground acceleration of different type of soil.

Table 6.1B: Peak Ground Acceleration

Site Classes	PGA
D=1.6*0.153g	0.245g
D=1.6*0.153g	0.245g
C=1.2*0.153g	0.186g
B=1*0.0153g	0.153g
A=0.8*0.153g	0.122g

The table 6.1B shows that there are different types of acceleration on different type of soil. The effect of earthquake damage varies according to local soil conditions. Where, PGA values increase, shaking of ground also increase. And, when PGA value decreases, shaking also decreases. Above mention clears strong rock would sustain less severe. Weak rock, residual and colluvial soils have more severity than type of Strong rock.

Map 6.1B: Ilam Municipality Under Peak Ground Acceleration



6.2 Earthquake Intensity

Ground motion intensity is site specific, whereas the earthquake magnitude is earthquake specific. It is a function not only of the earthquake magnitude and its distance to site, but on the site soil conditions and the orientation of the fault with respect to site.

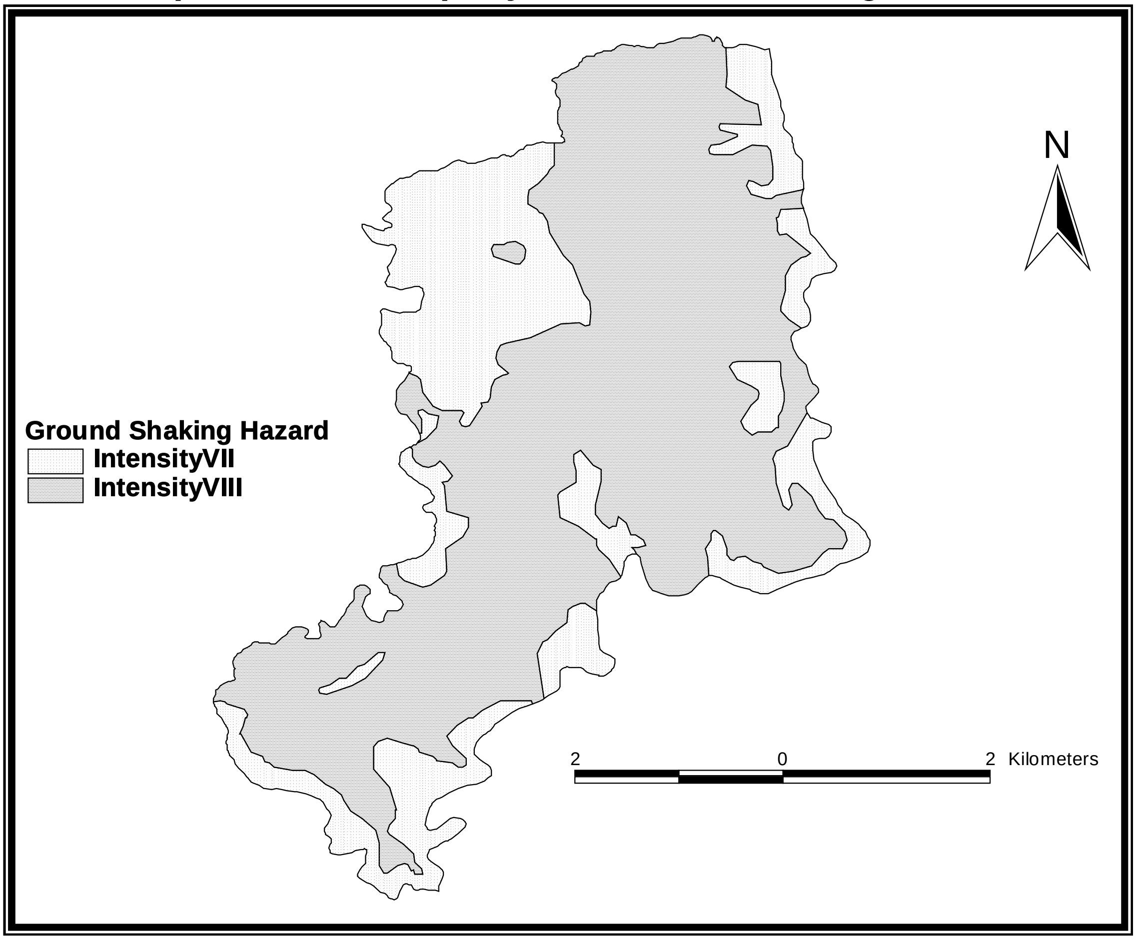
Four type of earthquake intensity were selected for this investigation. These events are indicated in Table 6.2.

Table 6.2: Earthquake Intensity in the Area

PGA(g)	Earthquake Intensity(MMI)
0.05-0.10	VI
0.10-0.20	VII
0.20-0.35	VIII
>0.35	IX

In Table 6.2 intensity VII and VIII magnitudes are seen as reflective of the representative earthquake for the region. Scenario VII magnitudes have half unit higher than the representative event. These magnitudes are interpreted as maximum credible for these locations. Magnitude VIII would appear to represent a disruptive an event, and potentially more so. it can be seen the Map 6.2.

Map 6.2: Ilam Municipality under Ground Shaking Hazard



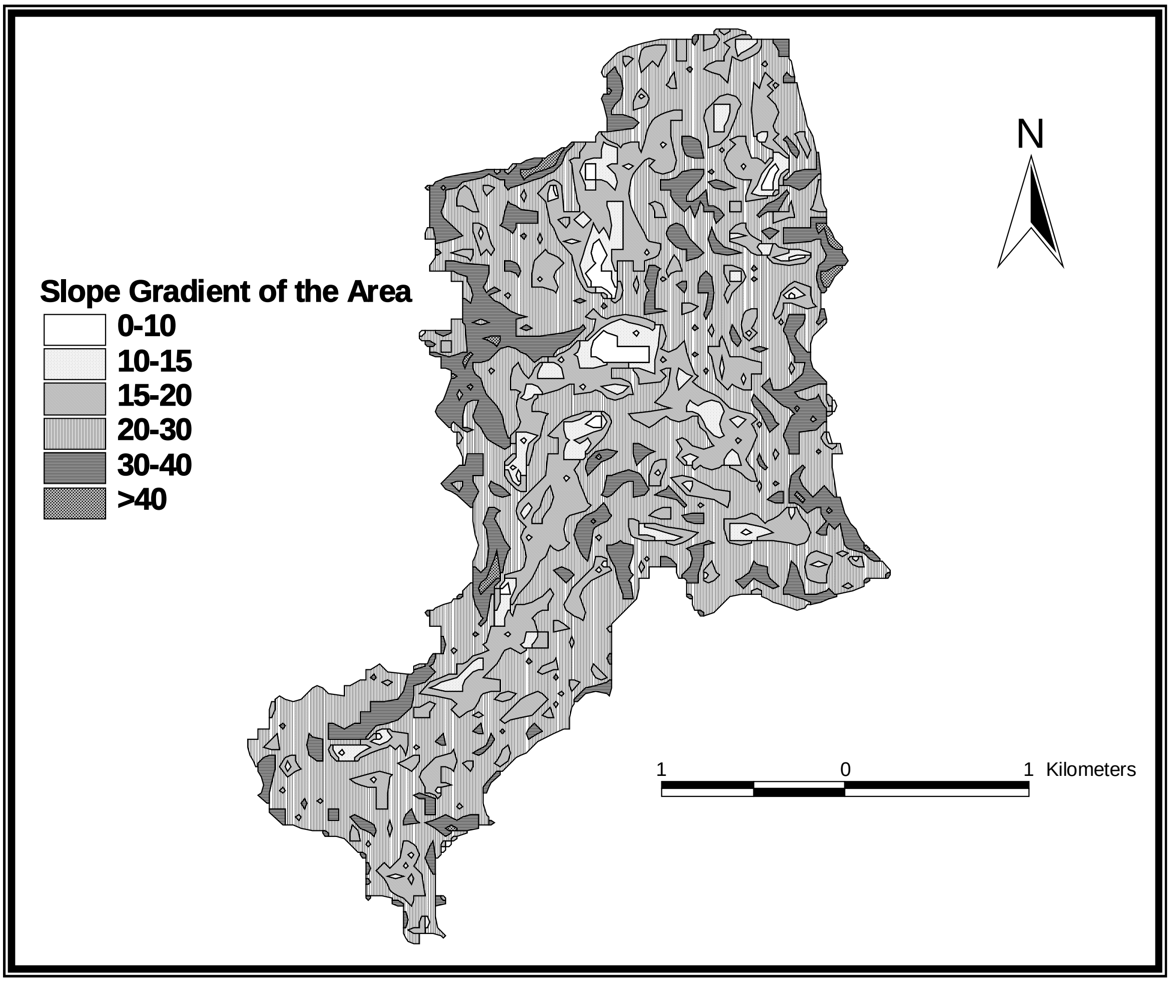
Source: Derived From Peak Ground Acceleration Map 6.1

6.3 Landslide Hazard

Landslide is the down slope movement of masses of earth under the force of gravity (Tianchi, 1996). Landslides are most widely manifested earthquake induced geological effects in the mountain terrain. Shaking of earthquake generates extra driving force which brings rock or soil mass to sliding down the slope (Pandey, 1999). Landslides induced by earthquakes depend upon the parameters of the earthquake such as magnitude, fault and spatial distance from the epicenter of the earthquake. And, geological, morphological and engineering parameters of the unstable rock or soil mass.

Evaluation of landslide hazards requires the characterization of the landslide susceptibility of soil and geologic conditions of a region. Susceptibility is characterized by the geologic group, slope angle and critical acceleration. Landslide susceptibility is measured on a scale of I to IX(HAZUS99, 1999) with I being the least susceptible. Landslide susceptibility of different geologic groups has been evaluated corresponding to slope angle (Degrees). Generally, the area of more than 15^0 slope angles is hazardous for landslides. Slope angle of the area has been divided on the Map 6.3

Map 6.3A: Slope Gradient of Ilam Municipality



Source: Derived From Contour line

The probability of land sliding at any location is determined by comparing the induced peak ground acceleration (a_{is}) with the assessed distribution for critical acceleration a_c. thus, at any location, there is specified probability of having a landslide susceptible deposit, and landsliding either occurs or does not occur within susceptible deposits depending on induced peak ground acceleration (a_{is}) exceeds the critical acceleration (a_c).Generally it is expressed as equation:

$$\mathbf{a_c / a_{is}} < 1 = \text{landslide}$$

a_{is} is the induced peak ground acceleration

a_c is the critical acceleration for particular susceptibility category

Down slope deformations occur during the time periods when the induced peak ground acceleration within the slide mass (a_{is}) exceeds the critical acceleration (a_c). In general, smaller the ratio (below 1) of ac to a_{is}, the greater is the number and duration of times when down slope movement occurs, and thus the greater is the total amount of down

slope movement.

Table 6.3A: Landslide Susceptibility for different Soil Group on Particular Slope

Soil Group	Geologic Group	Slope Angle					
		0-10	10-1 5	15-20	20-30	30-40	>40
		Susceptibility Category					
Residual Soil	C	V	VI	VII	IX	IX	IX
Colluvial Soil	C	V	VI	VII	IX	IX	IX
Weak Rock	B	None	III	IV	V	VI	VII
Moderately Strong Rock	A	None	None	I	II	IV	VI
Strong Rock	A	None	None	I	II	IV	VI

Source: HAZUS99, 1999

Landslide susceptibility categories are assigned as a function of geologic group, slope angle and soil group in table 6.3A. The critical acceleration is then estimated for the respective geologic conditions and the slope angle.

Table 6.3B: Critical Accelerations (ac) for Susceptibility Categories

Susceptibility Category	None	I	II	III	IV	V	VI	VII	VIII	IX	X
Critical Accelerations(g)	None	0.60	0.50	0.40	0.35	0.30	0.25	0.20	0.15	0.10	0.05

Source: HAZUS99, 1999

Landslide susceptibility is categorized as a function of critical acceleration. In general, the smaller the value of critical accelerations there is high susceptibility for landslide.

The amount of down slope movement also depends on the number of cycles of ground shaking. Since number of cycles increase with earthquake magnitude, deformation tends to increase with increasing magnitude for given values of ac and a_{is}.

The amounts of down slope movements are determined using the following expression:

$E\ (Landslide)=E(a_c/a_{is})*a_{is}*n$……………………………..equation(1)

Where,

$E(a_c/a_{is})$ is the expected landslide

a_{is} is the peak ground acceleration

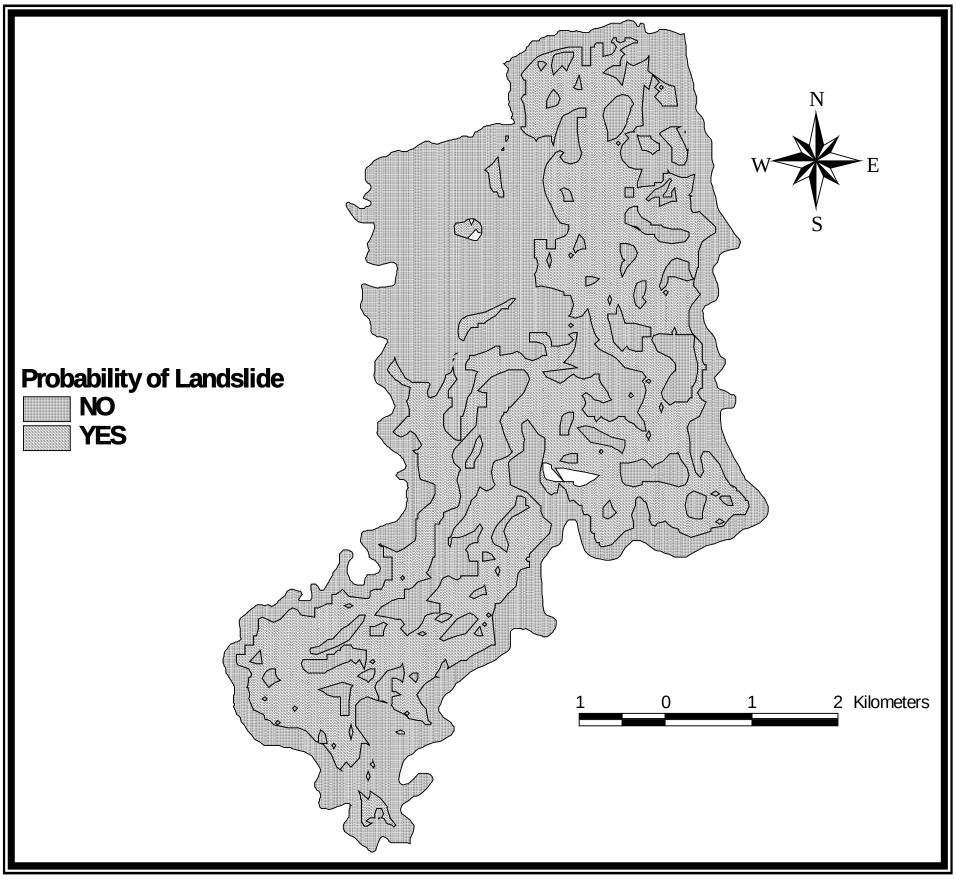
n is the number of cycles

And, A relationship between number of cycles and earthquake moment magnitude (M) is based on

$n=0.3419M^3-5.5214M^2+33.6154M-707692$……………….equation(2)

The induced peak ground acceleration within the slide mass a_{is}, represents the average peak acceleration within the entire slide mass. For shallow and laterally small slides, a_{is} is not significantly different than the induced peak ground surface acceleration a_1.

Map 6.3B: Landslide Possible Areas in Ilam Municipality



Source: Derived from PGA Map 6.1 and slope Map 6.3

The Above map 6.3B shows that most part of the Ilam Municipality could suffer from landslide. It mentions if the lifeline services lies in the landslide area , they would sustain heavy damage due to landslide.

CHAPTER VII
EARTHQUAKE VULNERABILITY ESTIMATION

Vulnerability is degree of loss to an element at risk resulting from the occurrence of a natural phenomenon (UNDP, 2004). It ranges from 0 to 1. Vulnerability is not natural, but the result of an entire range of constantly changing physical, social, economic, cultural, political, and psychological factors that shape peoples lives and create the environments in which they live. Vulnerability assessments are an indispensable complement to hazard assessment.

Seismic vulnerability of infrastructure is defined as the amount of expected damage induced to it by a particular level of earthquake intensity (UNDP, 2004). It describes the probability of failure of structures under different levels of ground shaking, which can be expressed in percentage. Loss is caused by a particular seismic hazard to the type of structures under consideration. Vulnerability analysis is a function of magnitude of an event and the type of elements at risk. There are different types of vulnerability: physical, social and economic. Especially the social vulnerability is like constant population change through time. It can be in the form of urban expansion or change in population (Westen, 2001).

The vulnerability assessment means to identify the hazard and the mapping and the assessing of social, economic and environmental vulnerabilities of the population. It describes as the probability of failure of a structure under different levels of ground shaking. There are two methods for the analysis of infrastructure vulnerability; namely qualitative and quantitative methods (Singh, 2005). The qualitative method is based upon the statistical evaluation of past earthquake damage. This method is suitable for non-engineering structures that have the same type of structural character. The quantitative method is based upon the numerical analysis of the structure. The infrastructure with the same material and construction type are grouped into one class. The performance of the infrastructure is predicted based upon design specifications and construction details.

The vulnerability of infrastructures is normally represented using a vulnerability curve of fragility curve. The curve expresses the expected severity of damage associated with the level of hazard (FEMA, 1999). There are a number of principal prerequisites for developing vulnerability curves (Krovvidi, 2001). These are economic loss data, the hazard for which the environment was subjected to and inventory based on location characteristics. The other factors, which contribute to the development of a sound vulnerability function, are hazard-structure interaction, damage statistics and knowledge of socio economic conditions of the region. The final vulnerability of a system could then be considered the aggregation of the vulnerability based on each criterion.

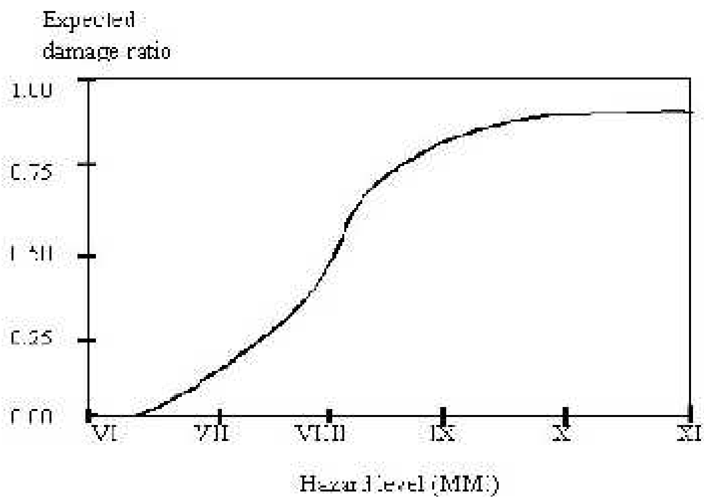


Figure 7: Schematic example of a vulnerability curve(NIBS, 1997)

In the country, the number of people has been growing at 2.23 % per year (CBS, 2001). People are migrating from rural to urban in search of employment. With the growth of the cities and population, changes also appear in the landscape. Hillsides are making space for new housing or workplaces. These are the same areas like poor supply of the lifeline facilities. Buildings having poor built and large density are at risk. On the other hand, concentration of population demands for better services, where city authorities are burdened with problems connected to the supply of water, telecommunication, gas, and energy (MuAN, 2007). Destruction of these lifelines in an earthquake event will therefore, create impact on population living in urban areas.

Urban sprawl and unplanned settlement with little sensible construction may add to this vulnerability since collapsing buildings increase the number of victims of earthquakes. High rise buildings, large underground shopping centers, basement structures are increasing rapidly. As a result, cost of building construction is also high. This will be a challengeable issue to the authorities.

Due to urbanization and rapid progress in motorization, problems of urban traffic are emerging. Increasing trend in traffic accidents may be anticipated in the future while the overhead bridges and elevated roads may increase the vulnerability of population to earthquakes.

Poverty is the main problem of the country. About 42 percent of the people are living below the poverty line (NLSS, 2004). People, who have to struggle every day just to survive and do not have the time or the strength to worry about more distant environmental and natural hazards, in practice, have to suffer more.

A noticeable feature in many parts is the scarcity of inhabitable land, and the concentration of the industries, factories, commercial centers, official buildings and recreational centers within the urban areas are seen as positively. This aspect is negated by migrant which increases their physical vulnerability. People migrate in large number for employment, recreation and the like. This is the increasing risk of exposure to future disaster events.

There have not been any studies about the physical conditions and damage states of physical infrastructure. Furthermore, there have not been any data of damage states of infrastructure in historic earthquakes in eastern Nepal. For that reason it is difficult to develop curve of earthquake intensity verses damage states for each type of infrastructure with a particular type of physical condition and location. In the study, Vulnerability assessment used to describe the expected or assumed earthquake performance characteristics of lifelines. Damage has been developed to calculate the quantitative relationships for direct damage and residual capacity. It is expressed using estimates of ground shaking intensity based on calculated PGA, specifying the location and type of infrastructures and fragility curves developed by FEMA (HAZUS99, 1999).

The hazard parameter used in vulnerability function is Peak Ground Acceleration (PGA) and Permanent Ground Displacement (PGD). The vulnerability evaluated is simply based on ground shaking not on structure of the infrastructures. In physical sense, it is rather not logical. The road transportation and water supply distribution might be physically damaged, if they are suffering from landslide or slope failures. Therefore, hazardous points are only those which are located on landslide areas.

7.1 Road Network under Landslide Hazard

Road transportation consists of roadways, bridges and tunnels. Roads are located on soft soil or fill or which cross a surface fault rupture can experience failure resulting in loss of functionality. Road transportation are vulnerable to both ground shaking and ground failure. Location of roads is very important in their vulnerability assessment since, the road usually cover large areas with various types of topography and geomorphology condition. Physical condition and material of the road seem less important in road vulnerability assessment.

Damage states describe the level of damage to the each road transportation. Damage states related to a damage ratio defined as the ratio of repair to replacement cost for evaluation, if direct economic loss. A total of five damage states are defined for road transportation(HAZUS99,1999). These are:

Slight/ minor (ds2). It is defined by slight settlement (few Inches) or offset of the ground.

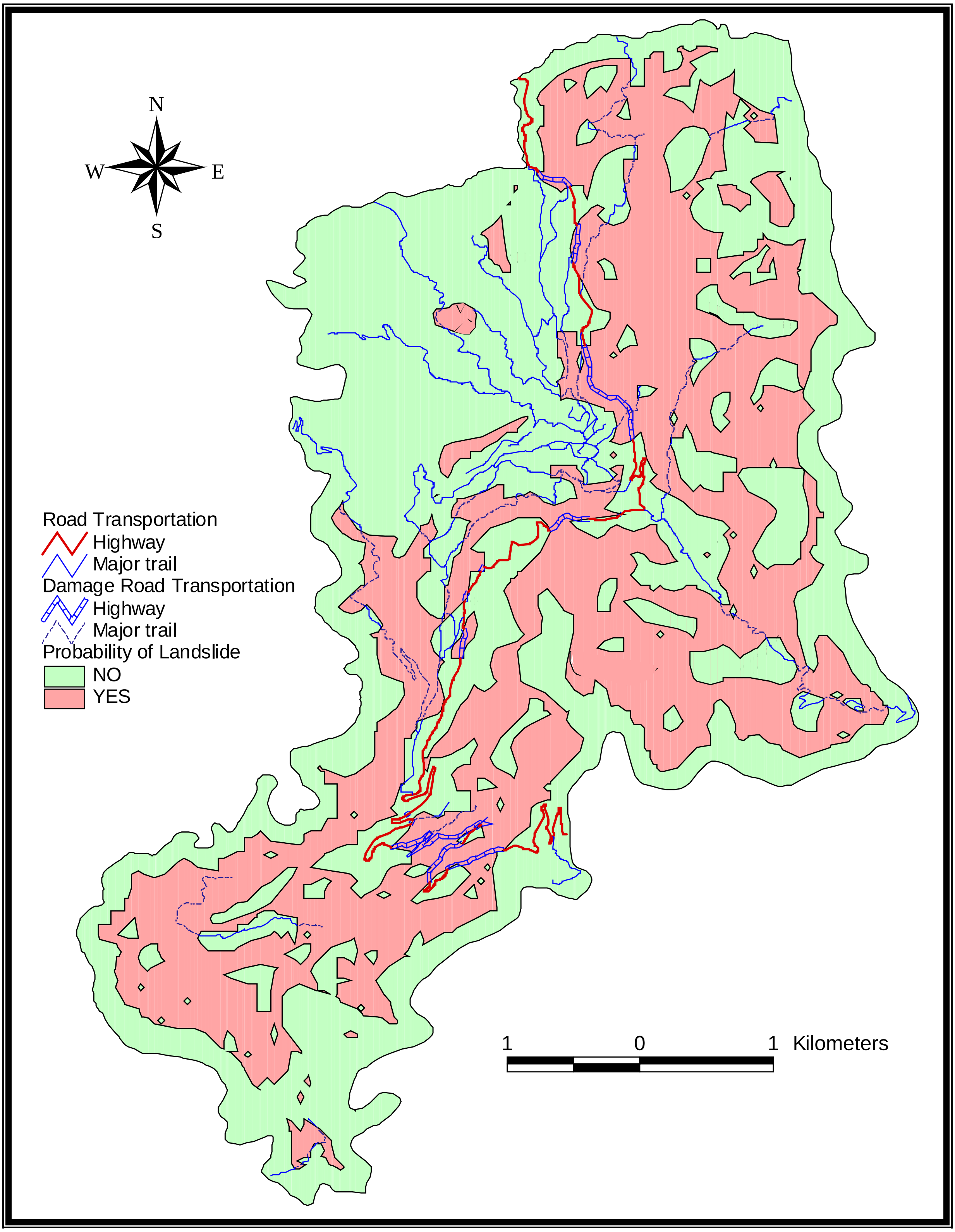
Moderate damage (ds3). Ds3 is defined by moderate settlement or offset of the ground.

Extensive damage (Ds4) is defined by moderate settlement of the ground(few feet).

Complete damage (ds5), it is defined by major settlement of the ground.

The road transportation is a highly redundant system, can be damage due to landslide, which in turn caused by earthquake. Damage is assumed at each location where the road crosses into a landslide zones.

Map 7.1: Road Damage Map



The Map 7.1 shows the distribution of damage road due to landslide. Roads, which are located in landslide prone area, as we can see in the map, consequently, in these locations have high potential damage.

Table 7.1: Potential Damage to Road Transportation				
Surface Type	**Length(Km)**	**Percent (%)**	**Damage**	**Damage (%)**
Black Topped	18.88	32.62	5.45	28.49
Earthen	34.55	59.69	11.16	58.34
Gravel	4.37	7.55	2.52	13.17
Stone Paved	0.08	0.14	0	0
Total	57.88	100.00	19.13	100.00

TYPE	Length(KM)	Percent (%)	Damage(KM)	Percent (%)
Highway	14.07	24.31	4.46774	23.35
Major trail	43.8	75.69	14.6632	76.65
Total	57.87	100	19.13094	100.00

Source: Derived from Above Map 7.1

Different type of road have possibility to damage due to landslide, which can be seen in the table 7.1. if such earthquake occur, about 5 km highway would be damaged and approximately 15 major trail would be damaged.

7.2 Distribution of Electric Transformers with Ground Shaking

Electric power systems are susceptible to earthquake damage. Facilities such as substations, generation plants and distribution circuits are most vulnerable to PGA, and sometimes PGD, if located in liquefiable or landslide zones. Therefore, the damage states for these components are defined in terms of PGA and PGD.

Five damage states are defined for electric power system components(HAZUS99,1999). These are none (ds1), slight/ minor (ds2), moderate (ds3) and complete (ds5).

Slight/ minor damage: For substations, ds2 is defined as the failure of 5% of the disconnect switches, or the failure of 5% circuit breaks, or by the building being in minor damage state.

For distribution transformers, ds2 is defined by the failure of 4% of all circuits.

Moderate damage: For substations, ds3 is defined as the failure of 40% of the disconnect switches or 40% of circuit breaks or failure of 40% of current transformers, or by the building being in moderate damage state.

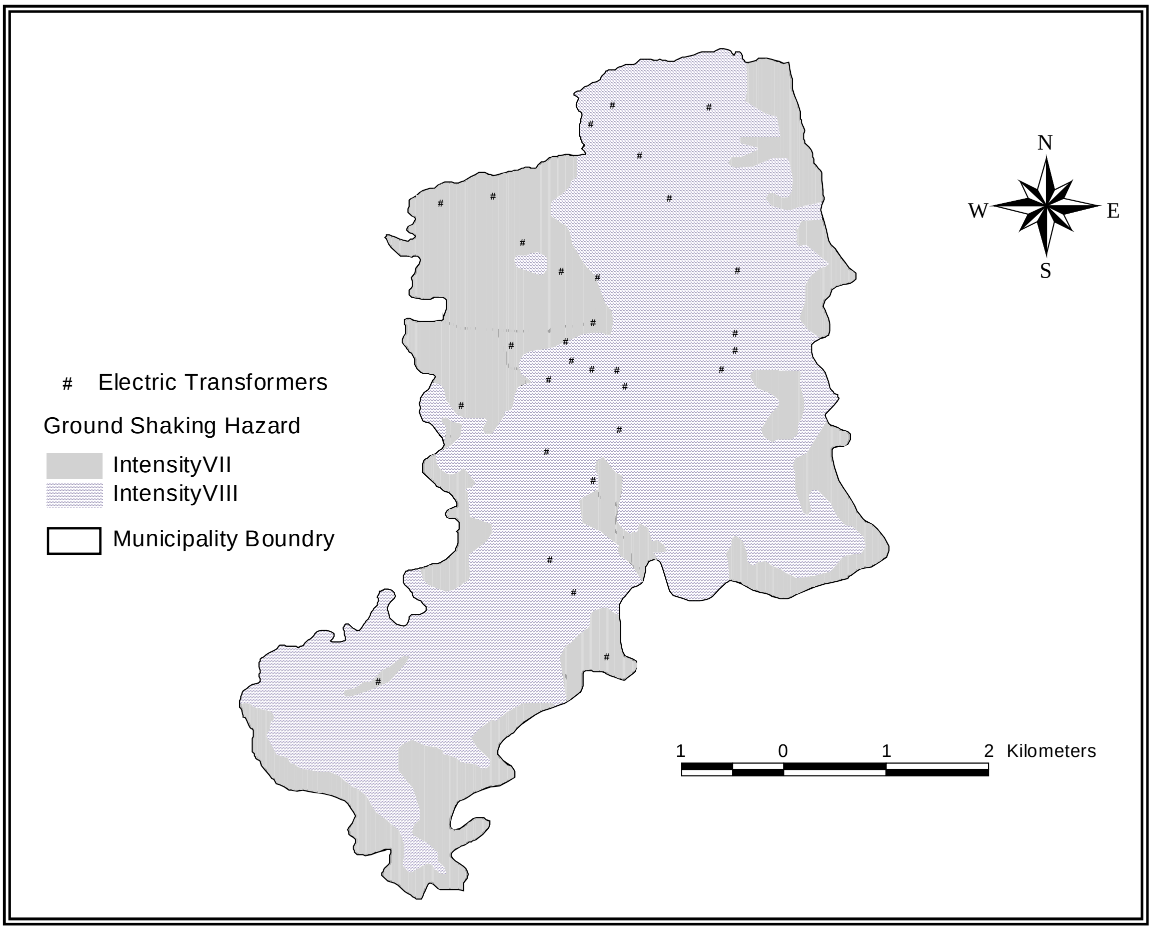
For distribution transformers, ds3 is defined by the failure of 12% of circuits.

Extensive damage: For substations, ds4 is defined as the failure of 70% of disconnect failure of 70% of disconnect switches, 70% of circuit breaks, 70% of current transformers or by failure of 70% of transformers or by the building being in extensive damage. For distribution transformers, ds4 is defined by the failure of 50% of all circuits.

Complete damage: For substations, ds5 is defined as the failure of all disconnect switches, all circuit breaks, all transformers, or all current transformers, or by the building being in extensive damage state.

For distribution transformers, ds5 is defined by the failure of all circuits.

Map 7.2A: Electric Hazard Map



Since most of the electric transformers are located in the area of intensity VIII. It can be expected to sustain heavy damage. Direct damage to the electric transformers as a result of the earthquake intensity, estimated using damage curves for electric transformers, is plotted in table.

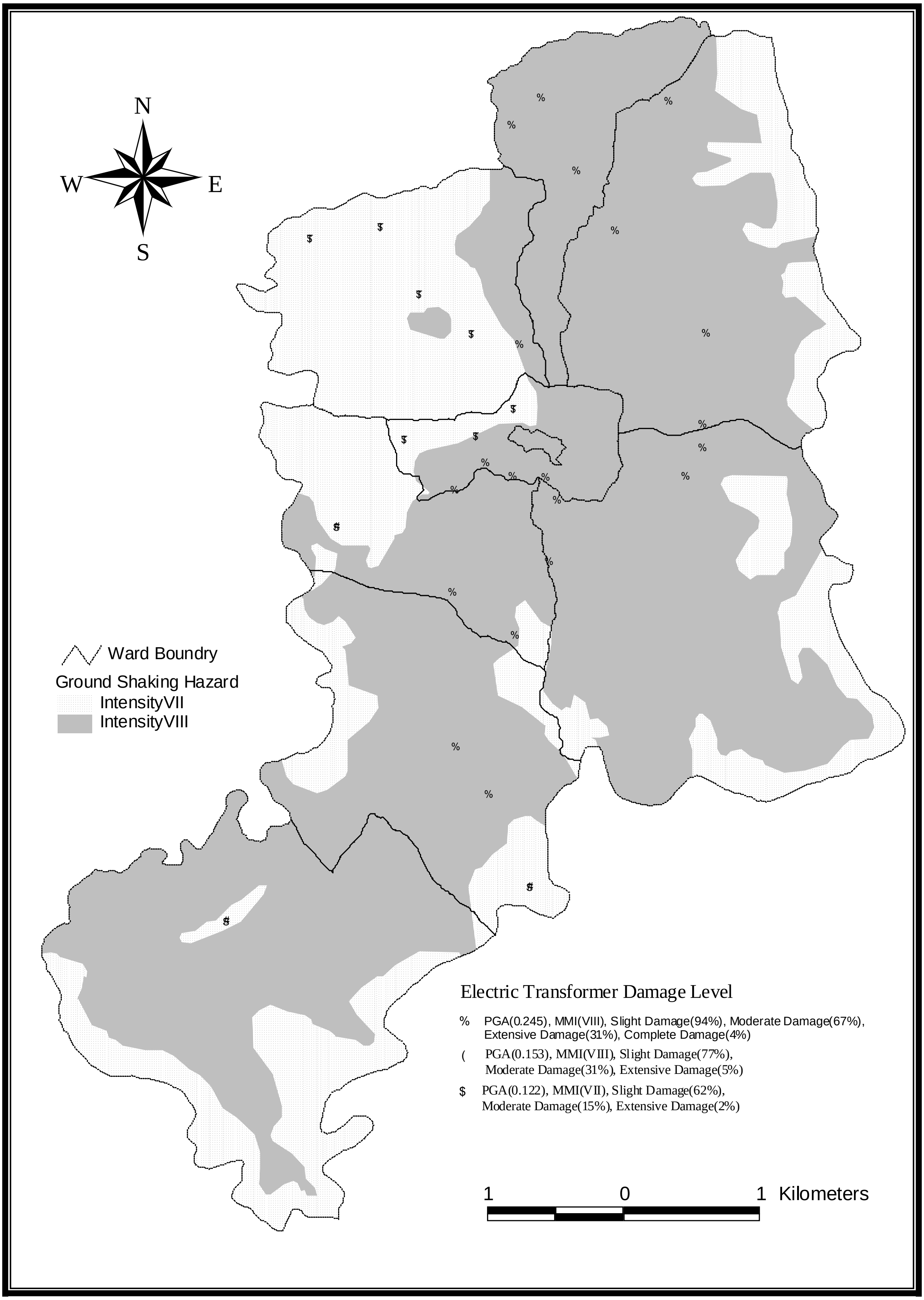
Table 7.2: Potential Damage Percent for Electric Transformers

Earthquake scenario	PGA	Slight/Minor (%)	Moderate (%)	Extensive (%)	Complete (%)
Intensity 7	0.122	62	15	2	-
Intensity 7	0.153	77	31	5	-
intensity 7	0.183	85	42	11	2
Intensity 8	0.245	94	67	31	4

Damage data estimates for the electric systems are based on curves for medium voltage transformers. Damage data for transformers indicate that damage to this facility type is expected to be greatest for the magnitude 8, in which 94% would sustain minor damage, 67% would sustain moderate damage, 31% would sustain extensive damage, and 4 5 would sustain complete damage.

Damage percent of the Electric transformers has been visualized in Map 7.2B

Map 7.2B: Electric Transformers Damage



7.3 Telephone Network with Ground Shaking

Communication facilities are susceptible to earthquake damage. Central offices and broadcasting stations are the only components of the communication system. Therefore, fragility curves are presented for these components only. Other components, such as cables and other lines, usually have enough slack to accommodate ground shaking and even moderate amounts of permanent ground deformations.

Direct damage output for a communication system includes probability estimates of component (i.e. central office/ broadcasting station) functionality and damage expressed in terms of the components damage ratio. Damage states for describing the level of damage to a communication facility are defined (i.e. slight, moderate, extensive, or complete).

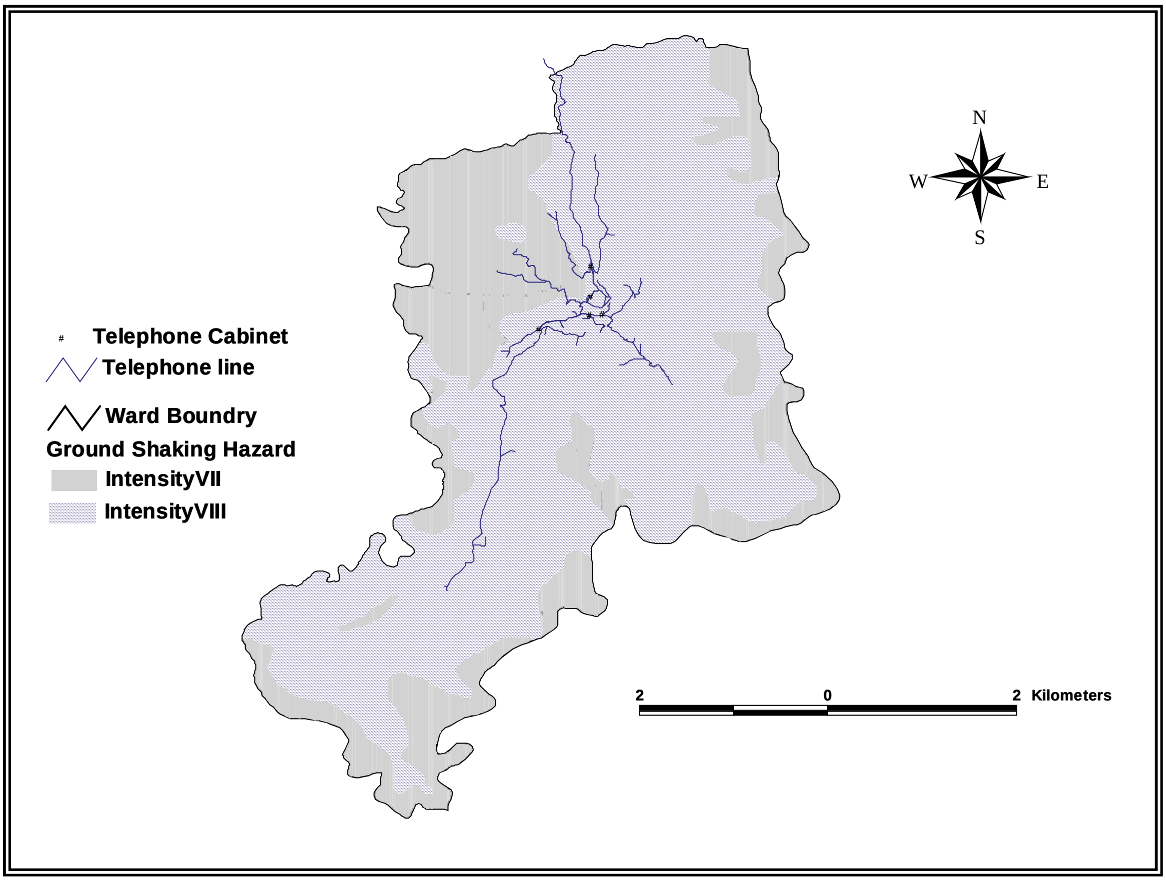
Slight/minor(ds2)*,* ds2 is defined by slight damage to the communication facility building, or inability of the center to provide services during a short period due to loss of electric power and backup power, if available.

Moderate damage (ds3*):* Moderate damage is defined by damage to communication facility building, few digital switching boards being dislodged, or the central office being out of service for a few days due to loss of electric power(power failure) and backup power(typically due to overloaded), if available.

Extensive damage (ds4) is defined by severe damage to the communication facility building resulting in limited access to facility, or by many digital switching boards being dislodged, resulting in malfunction.

Complete damage (ds5*).* It is defined by complete damage to the communication facility building, or damage beyond to digital switching boards.

Map 7.3A: Telephone Hazard Map



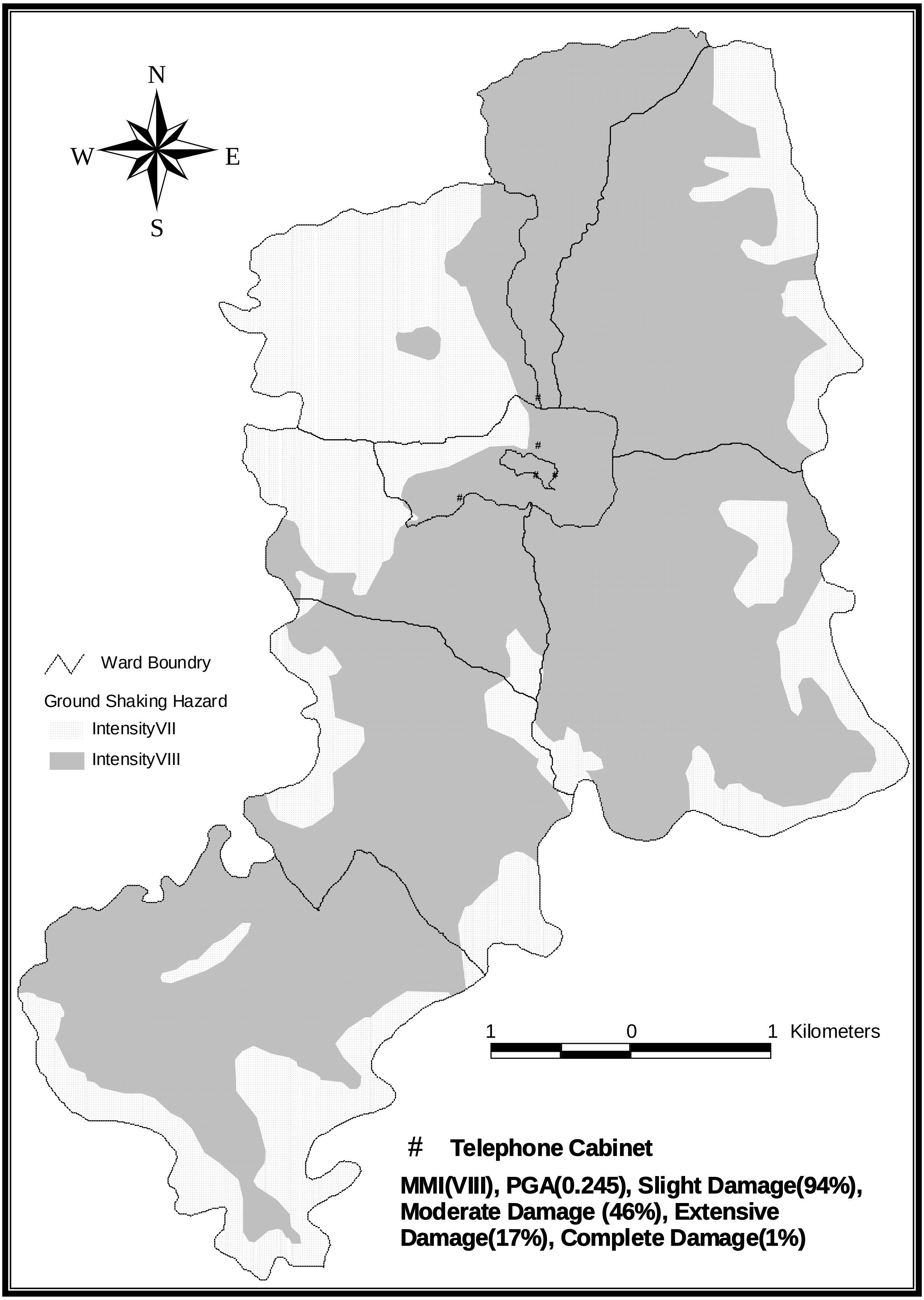
In the Map 7.3, Telephone Cabinet of the area has located in different parts. Based on the location of Telephone Cabinet it has been calculated damage percent of cabinet.

Table 7.3: Potential Damage Losses to Telephone Cabinet

Earthquake scenario	PGA	Slight/Minor (%)	Moderate (%)	Extensive (%)	Complete (%)
Intensity 7	0.122	47	5	1	-
Intensity 7	0.153	61	14	2	-
Intensity 7	0.183	74	24	7	-
Intensity 8	0.245	94	46	17	1

The direct damage data in table 7.3, suggests that the magnitude 8 events would caused the most extensive damage. 94% would sustain minor damage, 46 % would sustain moderate damage, 17% would sustain extensive damage and 1% would sustain complete damage. Map 7.3B shows the damage probability of telephone Cabinet.

Map 7.3 B: Telephone Cabinet Damage Map



7.4 Water Pipeline under Ground Shaking Hazard

Water supply system consists of supply, storage, transmission and distribution components. All of these components are vulnerable to damage during earthquakes, which may result in a significant disruption to the water utility network.

Water supply systems are susceptible to earthquake damage. Facilities such as water treatment plants, wells, pumping plants and storage tanks are most vulnerable to PGA, and sometimes PGD, if located in liquefiable or landslide zones. Therefore, the damage states for these components are defined and associated with PGA and PGD.

Damage states describing the level of damage to each of the water system components are defined (slight/ minor, moderate, extensive or complete), while for pipelines, the number of repairs/km is the key parameter. Pipes that are less than 20" m diameter are defined as small, while pipes with diameter greater than 20" are defined as large.

Slight/ minor damage (ds2), For water storage tanks, ds2 defined by the tank suffering minor damage without loss of its contents or functionality. Minor damage to the tank roof to water sloshing, minor cracks in concrete tanks, or localized wrinkles in steel tanks fits the description of this damage state.

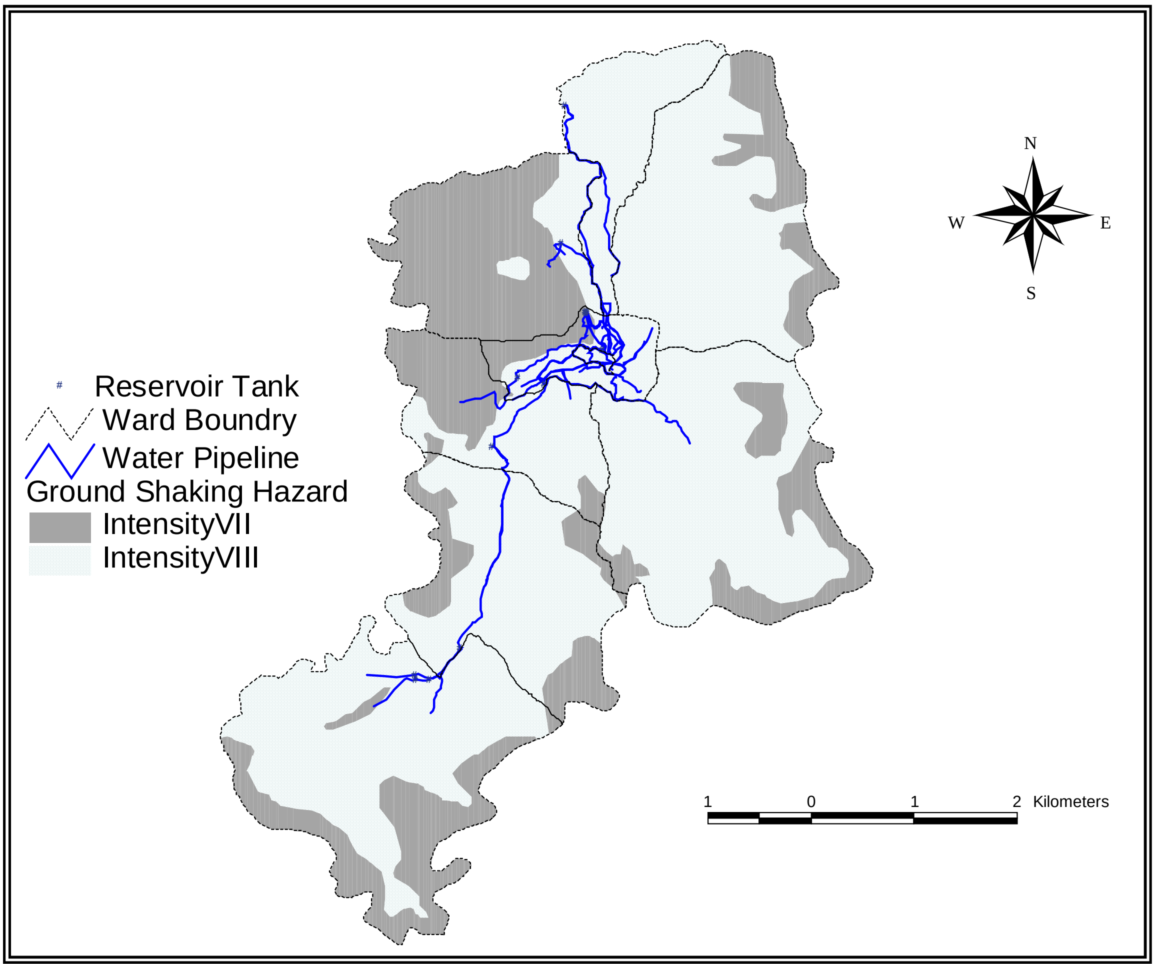
Moderate damage (ds3), it is defined by the tank being considerably damaged, but only minor loss of content. Elephant foot buckling for steel tanks without loss of content or moderate cracking of concrete tanks with minor loss of content fits the description of this damage state.

Extensive damage (ds4), ds4 is defined by the tank being severely damaged and going out of service. Elephant foot buckling for steel tanks with loss of content, stretching of bars for wood tanks, or shearing of wall for concrete tanks fits the description of this damage state.

Complete damage (ds5), is **defined** by the tank collapsing and losing all of its content.

For pipelines, two types of damage states are considered. These are leaks and breaks. Generally, when a pipe is damaged due to ground failure (PGD), the type of damage is break, while when a pipe is damaged due to seismic wave propagation (PGV), the type of damage is likely to be joint pull-out or crushing in the bell. It is assumed that damage due to seismic waves will consist of 80% leaks and 20% breaks, while damage due to ground failure will consist of 20% leaks and 80% breaks.

Map 7.4A: Water Supply Hazard Map



Map 7.4A shows the location of different type of reservoir tank. Reservoir tank are located in different parts of the area. In the case, earthquake damage can varies according to location of reservoir tank.

Table 7.4A: Potential Damage Percent for Concrete Water Tank for Each Scenario

Earthquake scenario	Slight/Minor (%)	Moderate (%)	Extensive (%)	Complete (%)
Intensity 7	25	4	-	-
Intensity 7	38	9	1	-
Intensity 7	50	12	2	-
Intensity 8	70	27	3	1

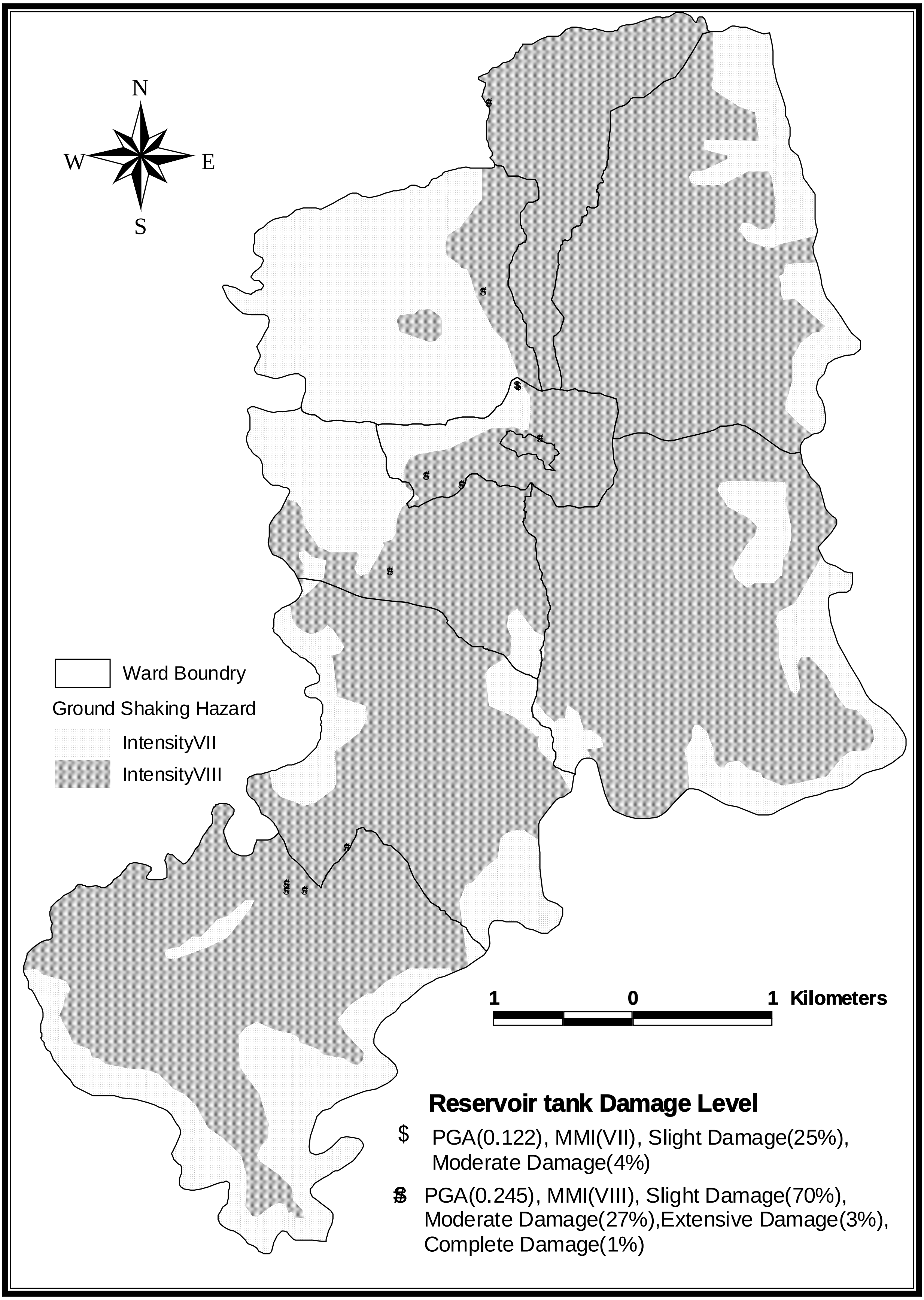
Table 7.4 B: Potential Damage Losses for Steel Water Tank

Earthquake scenario	Slight/Minor (%)	Moderate (%)	Extensive (%)	Complete (%)
Intensity 7	20	-	-	-
Intensity 7	40	-	-	-
Intensity 7	50	2	-	-
Intensity 8	75	7	1	-

Direct damage data for water tanks summarized in table 7.4A and table 7.4B, indicate that this facility type would be severely impacted in scenario events. The impacts are most severe in the Magnitude 8. For these scenario earthquakes, 70% concrete tank would sustain slight/minor damage, 27% would sustain moderate damage, 3% would sustain extensive damage and 1% would sustain complete damage.

The reason for the severe damage to water tank in the magnitude 7 and 8 is assumed to be strongly correlated with poor ground conditions and construction practices. Damage of water tank has been visualized in Map 7.4B.

Map 7.4 B: Water Tank Damage Map



7.5 Petrol Pump with Ground Shaking Hazard

Petrol pumps are vulnerable to damage during earthquakes. Facilities such as refineries, pumping plants and tank farms are most vulnerable to PGA and sometimes PGD, if located in liquefiable of landslide zones. Therefore, damage states for these components are associated with these ground motion parameters.

Five type of damage states are defined for petrol pump. These are none (ds1), slight/minor (ds2), moderate (ds3), extensive (ds4) and complete (ds5).

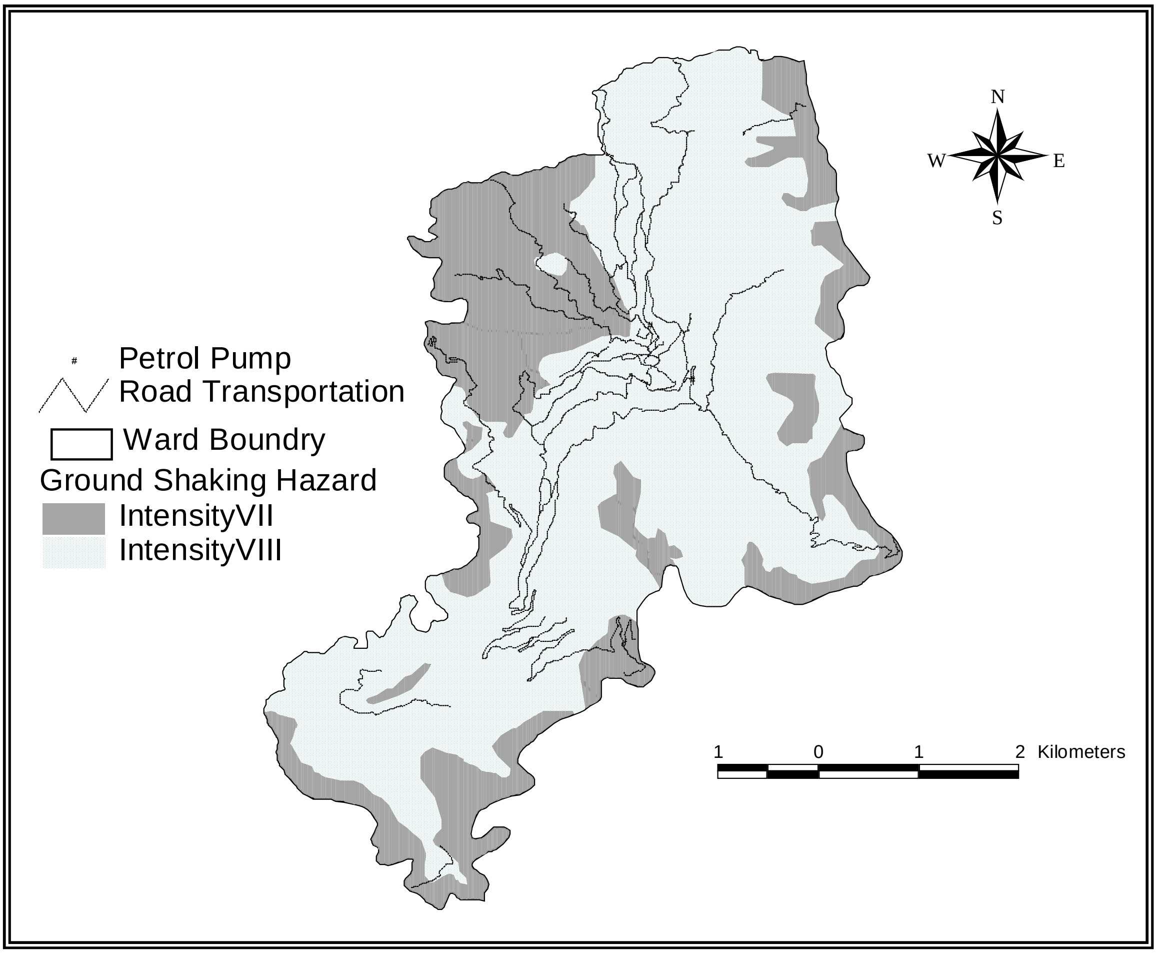
Slight/minor (ds2) is defined by malfunction of plant for short time(less than three days) due to loss of backup power or light damage to tanks.

For tank forms, moderate damage (ds3) is defined by malfunction of tank farm for a week or so due to loss of backup power, extensive damage to various components, or considerable damage to tanks.

Extensive damage (ds4) is defined by the tanks being extensively damaged, or extensive damage to elevated pipes.

Complete damage (ds5), ds5 is defined by the complete failure of all elevated pipes, or collapse of tanks.

Map 7.5A: Petrol Pump with Ground Shaking Hazard



Petrol pump behavior during an earthquake can be very complex. Petrol pumps are located in the area of MMI VIII. shaded area of the map is the area of soft soil. Since, Petrol pumps are located with having peak ground acceleration 0.245 regions. Only those scenario earthquakes affecting these regions will negatively impact this facility type. Damage probability of petrol pumps was assessed in table 7.5

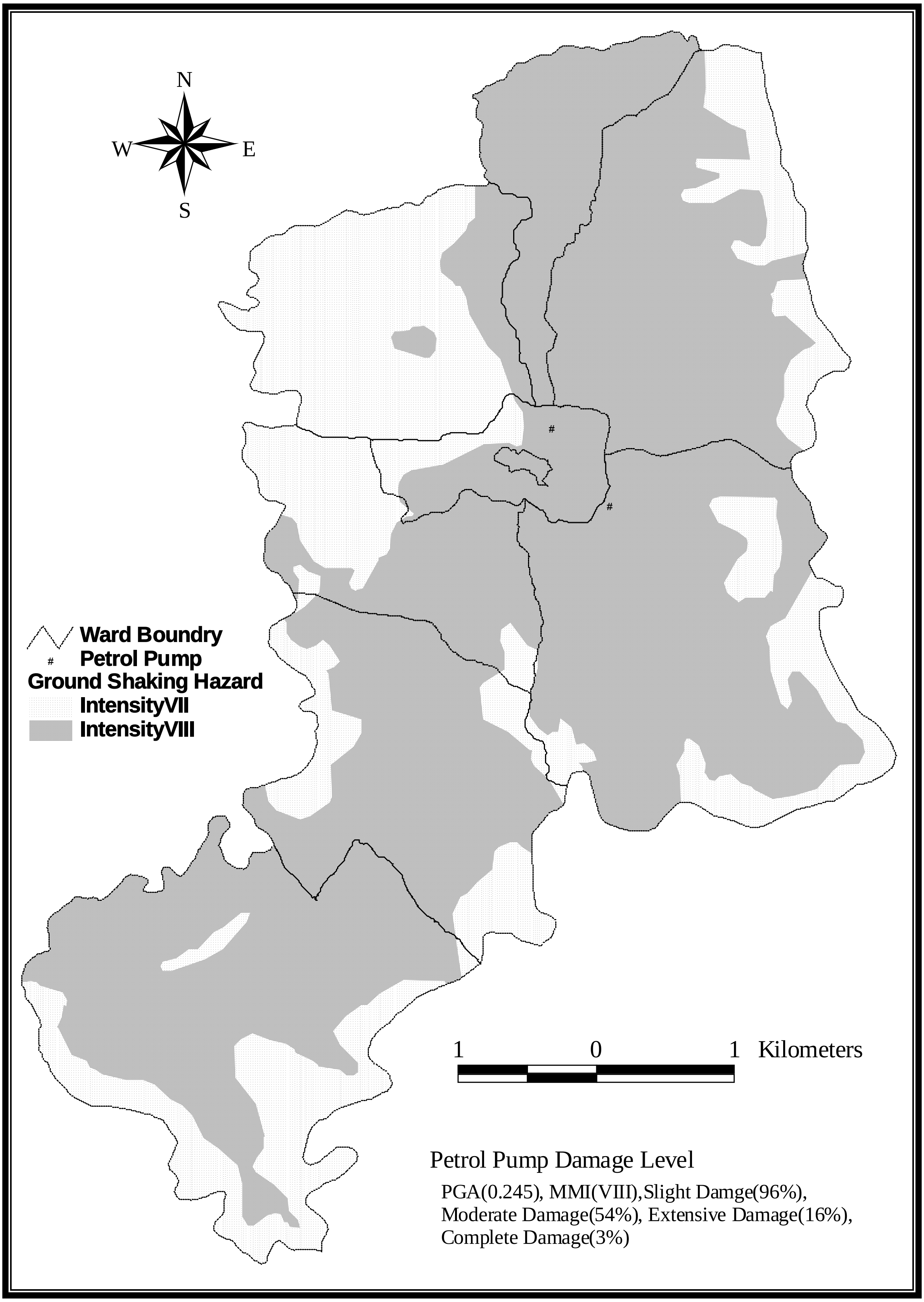
Table 7.5: Potential Damage Losses to Petroleum Tanks

Earthquake scenario	PGA	Slight/Minor (%)	Moderate (%)	Extensive (%)	Complete (%)
Intensity 7	0.122	47	12	-	-
Intensity 7	0.153	62	23	3	-
Intensity 7	0.183	76	34	6	-
Intensity 8	0.245	96	54	16	3

As in the case of petroleum tank, direct damage to this facility type will be more severe for the magnitude 7 and 8, 96% would sustain slight/minor damage, 54% would sustain moderate damage, and 16% would sustain extensive damage. 3 %

would be similarly affected by the magnitude 8. It has been visualized in the Map 7.5 B.

Map 7.5 B: Petrol Pump Damage Map



CHAPTER VIII

SUMMARY CONCLUSIONS AND RECOMMENDATIONS

8.1 Summary and Conclusion

The research has been carried out step by step to draw some conclusions about seismic behavior of public infrastructures.

Nepal is a high earthquake vulnerable country in the world. It has experienced several earthquakes in the past resulting in a large number of deaths and severe property damage. Situated in the Eastern part of Nepal, Ilam municipality is a capital of both Mechi Zone and Ilam District. Most of structures and lifelines services are built up without seismic coding. The frequent occurrence of earthquake clearly demonstrates the urgent need of study of earthquake risk assessment of lifeline services to reduce the impact of earthquake in the city. The devastating effect of an earthquake can be minimized to a great extent by hazard mapping, vulnerability analysis and risk mapping.

Lifeline is an earthquake engineering term denoting those systems necessary for human's life and urban functions, without which large urban regions cannot exist. Lifelines, basically covey food, water, fuel, energy, information and other materials which are necessary for human existence.

Vulnerability is used as a measure of the damage suffered by a structure due to seismic activity. Vulnerability to ground movement is determined by the structure itself. Therefore, the vulnerability of a system does not depend on the local seismic risk. In the study vulnerability indicates that a structure may be vulnerable in spite of being located in a seismically safe area.

Physical vulnerability of an infrastructure is the expected as degree of direct damage to the physical infrastructure given in a specified level of hazard. It is portrayed by vulnerability curves, depicting the expected severity of damage associated with the level of hazard. Several criteria like, design code, shape, material, age, embankment height etc are used to develop the vulnerability curves. The use of these criteria depends on each developed method.

The HAZUS method is a data demanding method. The HAZUS methodology requires various parameters, which can be categorized into four main parts: namely, earthquake characteristic parameters, ground motion parameters, lifeline inventory classification and damage functions.

The earthquake characteristic parameters include earthquake location, fault characteristics, service information. These parameters are used for ERA using scenario earthquake.

The ground motion parameters include the soil classification, soil amplification factors, peak ground acceleration, peak ground displacement, spectral acceleration, and spectral displacement. In the study the researcher used these parameters to find out hazardous area.

The lifeline inventory classification requires geographical position of the services. The lifeline utility service was taken from DUDBC.

The vulnerability curve (Fragility curve) describes the destruction excess probability with respect to the earthquake physical parameters. To develop fragility curve of an area, lifeline services are classified to different groups according to their structural system. A fragility curve is offered for each group.

Ilam municipality has been taken as the study to test the lifeline vulnerability assessment in an earthquake. The main theme of this study is to analyze the vulnerability, level of damage and hazard. It will be helpful to identify most vulnerable areas in the Ilam municipality. The whole research was broadly divided into 8 chapters.

Population distribution in municipality is not regular. Buildings in core areas are multi-functional.

HAZUS method estimates the number of damages or the probability of a certain damage to be expected as result of an earthquake. The hazards considered in this vulnerability study were geological hazards, ground shaking and landslide have been considered in the estimation of the potential damage on case of a scenario earthquake resulting in intensities of VII and VIII in different parts of the Ilam Municipality.

PGA Map, MMI map can be used for evaluation of lifeline earthquake vulnerability in quantitative sense. Most of the services are located on the high MMI areas.

The road transportation in Ilam municipality is about 54 km highway and 108.50 km major trail long. The transportation consists mostly of gravel road and narrow. Transportation infrastructures are not only damaged by an earthquake itself but also by earthquake induced hazards. The main reasons that cause damages to roads are the deformation and movement of the ground. About 28.49 km black topped, earthen 58.34 km earthen road and 13.17 gravel road will damaged due to landslide.

In the case of water systems, electric network and telecommunication systems, It is shown that no damage occur at intensities below 6, a moderate number of damage at intensities between 6-8, and at higher intensities there is a higher number of damages up to catastrophic cases for intensities VII and VIII. Reservoir tank has little chance to work after heavy earthquake.

There has been insufficient capacity of Ilam hospital. To handle large number of victims, hospital bed, medical personals, and the capacity of the blood bank are not sufficient.

At most places heavy vehicles like fire engines can not move due to narrow roads. There is lack of search and rescue team and equipment. It would be better to manage them properly before disaster strikes.

8.2 Recommendations

The following recommendations are given to extend this work to gain some fruitful outcomes.

- On the level of vulnerability condition of services Municipal authorities should launched mitigation programmes.
- Work on soil structure interaction of lifeline structure.
- Work out on plane behavior of Lifeline infrastructures.
- Verification of analytical results like period experimentally with up to data.

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Appendix

Table1: Road Transportation in Ilam Municipality

ID	SURF_TYPE	TYPE	NAME	WIDTH	LENGTH(Mt)	FOOTPATH	CONDITION
1002074	Black Topped	Highway	Buddha Marg	5	2358.49	Y	C
1002062	Black Topped	Highway	Indra Pradhan Marg	5	514.712	Y	C
1002064	Black Topped	Highway	Parijat Marg	3.5	473.505	Y	C
1002063	Black Topped	Highway	Sahid Sukraraj Marg	5	3395.56	Y	C
1002061	Black Topped	Highway	Sahid Dharmabhakta Marg	4.5	619.058	Y	C
1002060	Black Topped	Highway	Devkota Marg	5	654.428	Y	C
1002036	Black Topped	Highway	Saraswati Rai Marg	5	1327.85	Y	C
1002057	Black Topped	Highway	Sahid Gangalal Marg	5	4727.66	Y	C
1002039	Earthen	Major trail	Araniko Marg	3.5	1051.44	Y	PH
1002065	Earthen	Major trail	Bhakti Thapa Marg	4	643.259	Y	PH
1002059	Earthen	Major trail	Narendranath Bastola Marg	4	3665.4	Y	PH
1002058	Earthen	Major trail	Tek Bahadur Bista Marg	4.5	1062.69	Y	PH
1002067	Earthen	Major trail	Kale Damai Marg	4	588.229	Y	PH
1002069	Earthen	Major trail	Singhamai Devi Marg	4	1452.58	Y	PH
1002037	Earthen	Major trail	Kamal Parajuli Marg	3.5	446.105	Y	PH
1002017	Earthen	Major trail	Ratna Marg	3	526.495	Y	PH
1002046	Earthen	Major trail	B.P. Marg	3.5	2224.46	Y	PH
1002028	Earthen	Major trail	Madan Ashrit Marg	3	502.791	Y	PH
1002072	Earthen	Major trail	Narbu Rai Marg	4	320.027	Y	PH
1002056	Earthen	Major trail	Smriti Marg	4	638.284	Y	PH
1002027	Earthen	Major trail	Anil Marg	2.75	1287.39	Y	PH
1002054	Earthen	Major trail	Kabi Yuddhaprasad Mishra Marg	3	325.006	Y	PH
1002053	Earthen	Major trail	Bhangtar-Soyak Road	0	768.435	Y	PH
1002052	Earthen	Major trail	Bhupi Sherachan Marg	5	431.52	Y	PH
1002051	Earthen	Major trail	Er. Devratna Maharjan Marg	4	330.409	Y	PH
1002050	Earthen	Major trail	Namuna Marg	3	406.377	Y	PH
1002049	Earthen	Major trail	Sahid Laxmi Pandey Marg	3.5	223.811	Y	PH
1002071	Earthen	Major trail	Nanda Prasad Siwakoti Marg	3.5	317.558	Y	PH
1002043	Earthen	Major trail	Ganeshman Marg	3.5	619.427	Y	PH
1002047	Earthen	Major trail	Setidevi Marg	4	1937.51	Y	PH
1002018	Earthen	Major trail	Shrikrishna Marg	4	1164.99	Y	PH
1002030	Earthen	Major trail	Chiyabari Marg	4	459.552	Y	PH
1002029	Earthen	Major trail	Swabalamban Marg	3	98.5183	Y	PH
1002019	Earthen	Major trail	Gagarajgang Thapa Marg	3	627.592	Y	PH
1002021	Earthen	Major trail	Narayan Gopal Marg	4	117.909	Y	PH
1002073	Earthen	Major trail	Pandit Ramhari Marg	2.65	403.513	Y	PH
1002013	Earthen	Major trail	Padam Bahadur Dewan Marg	5	356.628	Y	PH
1002031	Earthen	Major trail	Bhakta Bahadur Dewan Marg	5	487.578	Y	PH
1002032	Earthen	Major trail	Beni Marg	3	482.933	Y	PH
1002055	Earthen	Major trail	Mayadevi Marg	3	1266.5	Y	PH
1002033	Earthen	Major trail	Balaguru Marg	2	251.468	Y	PH
1002045	Earthen	Major trail	Khagendra Nath Sharma Marg	3	850.872	Y	PH
1002040	Earthen	Major trail	Shramik Marg	3.5	758.409	Y	PH
1002068	Earthen	Major trail	Puspalal Marg	3.5	868.303	Y	PH
1002066	Earthen	Major trail	Panchhakanya Marg	3.5	697.497	Y	PH
1002048	Earthen	Major trail	Plumber Biru Marg	3	1486.43	Y	PH
1002044	Earthen	Major trail	Raghubir Marg	3	1451	Y	PH

1002075	Earthen	Major trail	Santa Gyandildash Marg	3	726.142	Y	PH
1002041	Earthen	Major trail	Ghanendra Chouhan Marg	3.5	2005.54	Y	PH
1002070	Stone Paved	Major trail	Devidas Marg	2.5	79.693	Y	N
1002026	Black Topped	Major trail	Ranabir Gurung Marg	5	358.346	Y	NC
1002023	Black Topped	Major trail	Narayansthan Marg	5	340.513	Y	NC
1002022	Black Topped	Major trail	Prakash Path	5	392.201	Y	NC
1002016	Black Topped	Major trail	Nikunja Path	5	121.847	Y	NC
1002015	Black Topped	Major trail	Bhanu Path	5	513.105	Y	NC
1002042	Black Topped	Major trail	Lekhanath Poudyal Marg	3	652.047	Y	NC
1002012	Black Topped	Major trail	Maisthan Marg	4	103.999	Y	NC
1002025	Black Topped	Major trail	Mahabir Samser Marg	3.5	495.757	Y	NC
1002020	Black Topped	Major trail	Bishnu Nabin Marg	4	199.389	Y	NC
1002011	Black Topped	Major trail	Mala Path	4	437.724	Y	C
1002035	Black Topped	Major trail	Mahananda Marg	5	894.986	Y	C
1002034	Black Topped	Major trail	Sahid Marg	5	301.67	Y	NC
1002024	Earthen	Major trail	Shital Marg	3.5	215.356	Y	PH
1002038	Gravel	Major trail	Kale Damai Marg	4	4366.94	Y	PH

Where,
C= Crack
PH= Pot holes
NC= Non-Crack

Table 2: Water Supply System

Tank_ID	AGE	WARD NO	CAPACITY	PLACEMENT	TYPE	SOURCE	PIPE MATERIL	PIPE_SIZE
11	2038	4	55000	Underground	Masonary	Devithane	HDP	1",2"
13	2040	5	10000	Underground	RCC	Bhalubanse	CI,HDP	2",1.5",1"
14	2046	5	16000	Underground	RCC	Bhalubanse	CI,HDP	2",1.5",1"
12	2056	5	8000	Underground	RCC	Bhalubanse	CI,HDP	2",1.5",1"
10	2036	3	60000	Underground	RCC	Sisne Muhan	CI,HDP	1",2"
2	2039	9	95000	Underground	Masonary	Gitang	CI	2"
1	2054	8	75000	Underground	RCC	Gitang	CI,HDP	1",1.5",50mm
7	2056	2	85000	Underground	RCC	Gitang	CI,HDP	1",2"
8	2045	2	85000	Areal	Fabric Glass	Gitang	CI	2"
5	2035	2	185000	Underground	RCC	Gitang	CI	1.5"
6	2045	2	360000	Areal	Fabric Glass	Gitang	CI	3"
4	2007	2	42830	Areal	RCC	Gitang	CI	1.5"
3	2007	2	32240	Areal	RCC	Gitang	CI	3"
9	2045	1	95000	Areal	Fabric Glass	Gitang	CI	3",6"

Table 3: Electric power systems

TRANSF_ID	LOCATION AREA	CAPACITY_KV
1002	Malbase	25
1001	Toribari	15
1003	Chureghati	25
1004	Tallo Singfring	25
1005	Near Parajuli Ho	50
1006	Khareldanda	50
1007	Mahabhir	50
1008	Tilkeni	100
1009	Substation	3311
1010	Narayansthan	100
1011	Army Camp	50
1012	District jail	50
1013	Shera	50
1014	Chain Camp	100
1015	Intake	100
1016	Power house	100
1017	Power House Hostel	100
1018	Head Tank	50
1019	Kureni	25
1020	Near Adarsha hig	50
1021	District Hospita	100
1022	Silikan	50
1023	Tundikhel	200
1024	Golbasti	50
1025	Bhagawati school	50
1026	Phulgacchi	25
1029	Nepal bank	100
1028	Nepal Telecom	50
1027	Green view Hotel	100
1030	Balangau	50

Table 4: Water Pipeline

PIPELINE_ID	DIAMETER	LENGTH	MATERIAL
3	32 MM	523.12700000000	HDP
3	32 MM	466.07300000000	HDP
2	1.5 INCH	378.51500000000	GI
3	32 MM	133.21900000000	HDP
2	1.5 INCH	373.06100000000	GI
3	25 MM	132.60100000000	HDP
3	25 MM	44.64090000000	HDP
3	25 MM	143.57100000000	HDP
3	25 MM	11.89260000000	HDP
3	25 MM	2718.18000000000	HDP
3	32 MM	440.56100000000	HDP
2	2 INCH	1100.85000000000	GI
3	32 MM	154.91200000000	HDP
2	2 INCH	786.92900000000	GI
1	1.5 INCH	5.91108000000	CI
2	2 INCH	18.31240000000	GI
2	2 INCH	13.99370000000	GI
2	2 INCH	68.05170000000	GI
3	40 MM	731.77100000000	HDP
2	2 INCH	299.76300000000	GI
3	32 MM	204.10500000000	HDP
3	40 MM	738.44000000000	HDP
3	50 MM	550.17600000000	HDP
3	63 MM	345.19200000000	HDP
3	32 MM	767.74400000000	HDP
3	40 MM	613.72800000000	HDP
2	1.5 INCH	215.32400000000	GI
3	50 MM	914.83700000000	HDP
3	63 MM	346.71000000000	HDP
2	2 INCH	1021.82000000000	GI
2	1.5 INCH	679.77100000000	GI
3	75 MM	223.21300000000	HDP
1	3 INCH	931.91600000000	CI
0	3 INCH	76.02030000000	HDP
3	32 MM	553.70000000000	HDP
3	40 MM	639.36500000000	HDP
1	3 INCH	1913.10000000000	CI
1	3 INCH	47.07900000000	CI
3	32 MM	293.38300000000	HDP
2	1 INCH	115.87200000000	GI
1	6 INCH	462.06200000000	CI
1	3 INCH	234.73800000000	CI
1	3 INCH	198.80400000000	CI
1	3 INCH	374.46100000000	CI
1	3 INCH	156.54000000000	CI

3	75 MM	114.34400000000	HDP
1	2.5 INCH	224.45200000000	CI
1	3 INCH	89.32030000000	CI
1	5 INCH	1205.12000000000	CI
1	6 INCH	513.37900000000	CI
1	3 INCH	564.45100000000	CI
1	6 INCH	251.50400000000	CI
1	3 INCH	524.16400000000	CI
1	3 INCH	779.07100000000	CI
1	5 INCH	327.32900000000	CI
2	1.5 INCH	367.11500000000	GI
2	1 INCH	92.35920000000	GI
2	1.5 INCH	171.76400000000	GI
2	1.5 INCH	488.58200000000	GI
2	2 INCH	227.69000000000	GI
2	1.5 INCH	286.14300000000	GI
2	2 INCH	207.03500000000	GI
2	1.5 INCH	278.32500000000	GI
2	2 INCH	289.28800000000	GI
2	3 INCH	934.77100000000	GI
2	0.5 INCH	504.58600000000	GI
2	1.5 INCH	1139.73000000000	GI
2	1.5 INCH	14.37200000000	GI
2	2 INCH	375.88800000000	GI
2	1 INCH	710.23700000000	GI
2	1 INCH	279.38000000000	GI
2	1 INCH	285.16300000000	GI
2	1.5 INCH	357.42700000000	GI
2	2 INCH	112.50200000000	GI
2	2 INCH	512.96900000000	GI

Table 5: Telecommunication System

Capacity	Id	Location	Distribution Line	Placement	Pole_material	Average length(M)
500	1003	Ratna Chowk	543	Areal	W,I,S	307
300	1001	Shanti chowk	253	Areal	W,I,S	197
300	1002	Birendra Chowk	292	Areal	W,I,S	121
400	1004	Pipal Chowk	332	Areal	W,I,S	1491

300	1005	Near NTC	227	Areal	W,I,S	451

Figure1: Damage Curve for Road Transportation

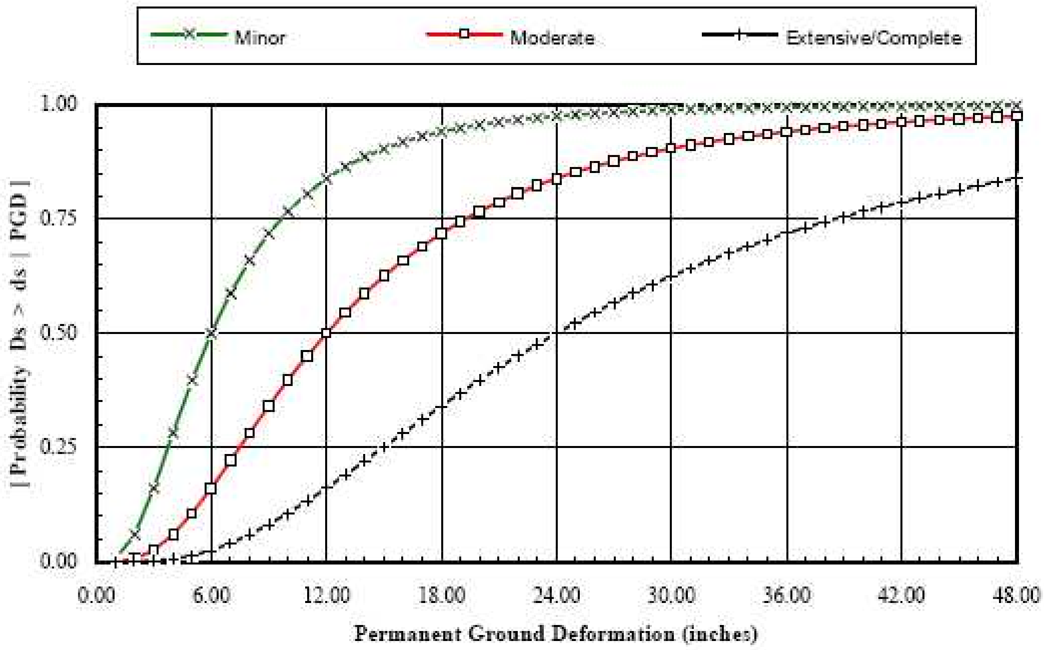

Figure2: Damage curve for Ground Concrete Tank

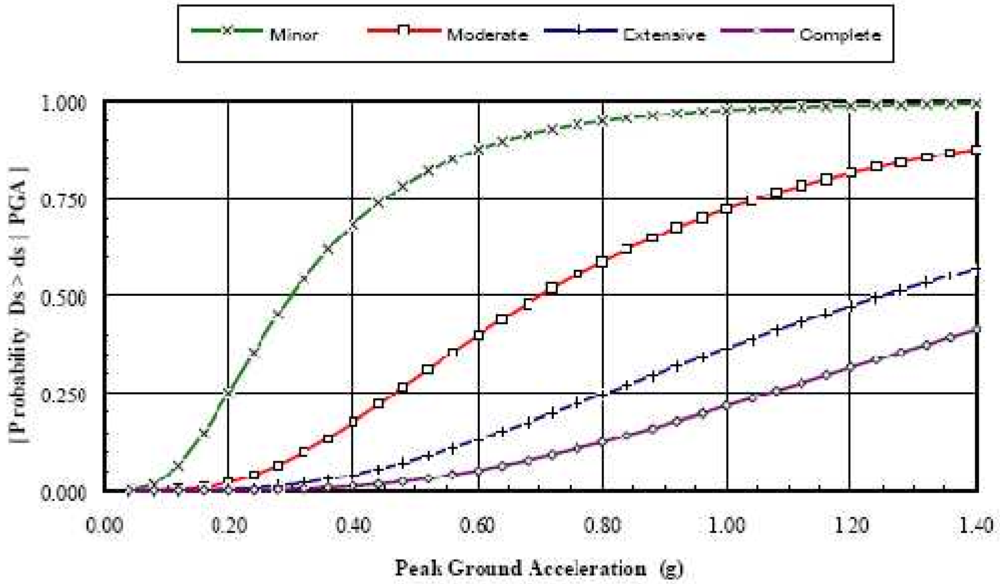

Figure3: Damage Curve for Ground Steel Tank

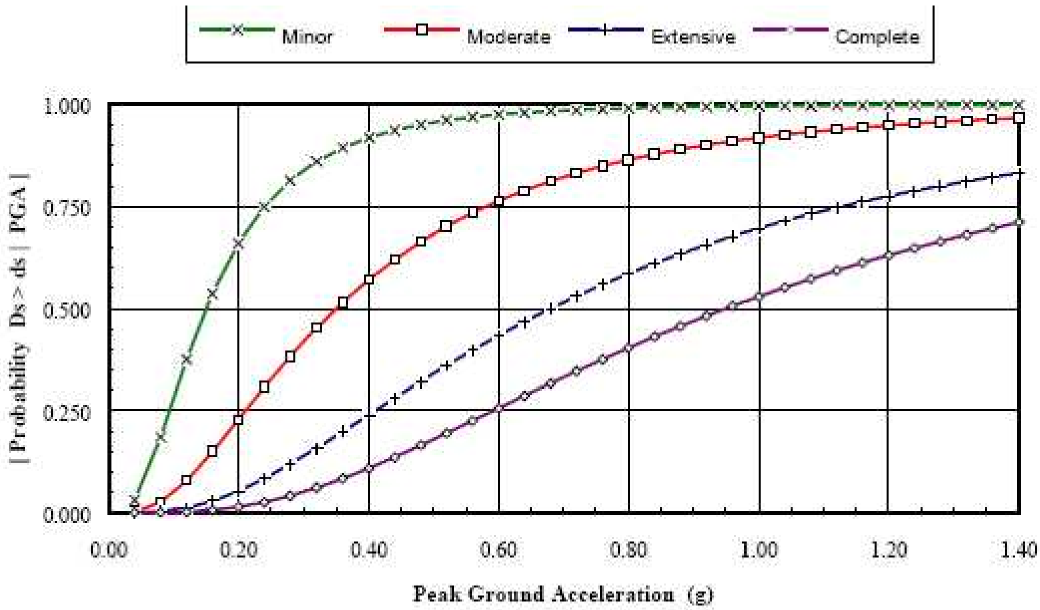

Figure 4: Damage Curve Petrol Pump

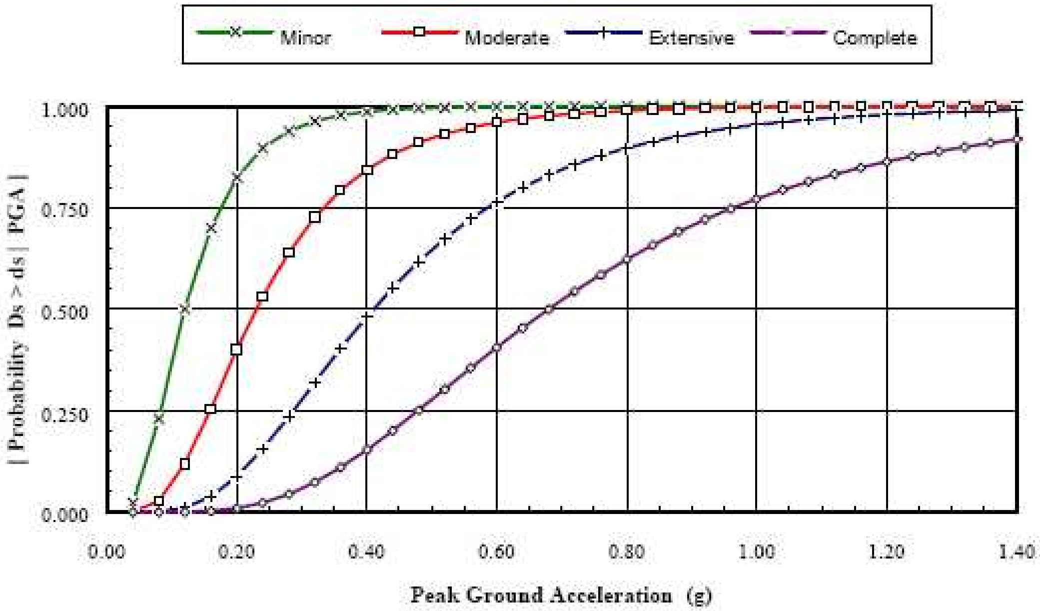

Figure 5:Damage curves for Electric Transformers

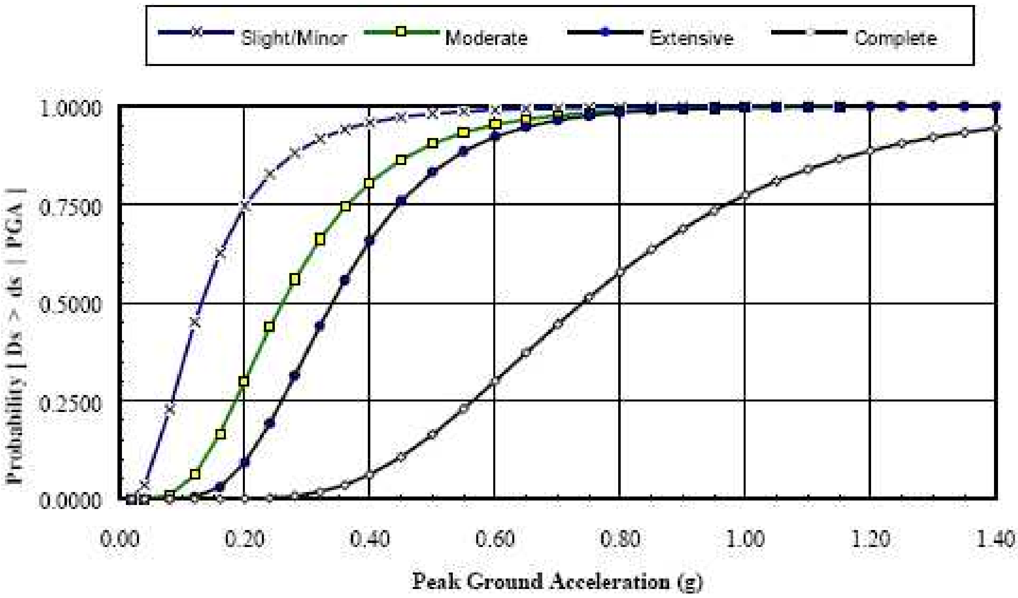

Figure 6:Damage Curve Telephone for Cabinet