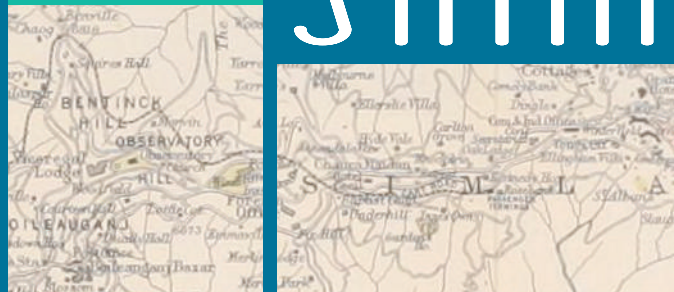

SHIMLA

Final Report

Report on Multi-Hazard Mapping and Analysis, Development of Exposure and Vulnerability Assessment (Physical, Economic, Social and Environment) and Risk Assessement; Capacity Assessment

May 2016

Acknowledgements

It has been a thought-provoking experience to work on the assessment of Multi-Hazard Risk and Vulnerability Assessment (HRVA) of the City of Shimla (Himachal Pradesh State) under the MHA-USAID - UNDP Partnership on Climate Risk Management in Urban Areas through Disaster Preparedness and Mitigation. Taru wishes to express its deep gratitude to Municipal Commissioner and Deputy Mayor of Shimla for their cooperation and support. A special thanks to all key informants/stakeholders who participated in this project and we are grateful for the significant contribution provided by the departments in Municipal Corporation i.e. Accounts, Architect Planner, Tax, Estate, Conservancy, Roads & Buildings, Water Supply & Sewerage, City Disaster Management cell and experts from other technical agencies and disaster management agencies at the state, district and city level.

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Authors: Ajay K Katuri, Umamaheshwaran Rajasekar, PhD

Team Composition: Ajay K Katuri (Team leader), Umamaheshwaran Rajasekar, PhD (Risk Assessment Expert), Anup Karanth (Deputy Team Leader & Institutional Assessment Expert), G.K Bhat (Policy Adviser), Navneet Yadav (Local Field Expert), Piyush Shah (MIS Expert), Jyotsna Vaish (GIS Analyst & Survey Manager), Shashank Mishra (Civil Engineer), Tejas Patel (Survey Manager).

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Final Report

Report on Multi-Hazard Mapping and Analysis, Development of Exposure and Vulnerability Assessment (Physical, Economic, Social and Environment) and Risk Assessement; Capacity Assessment

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Executive Summary

The state of Himachal Pradesh with Shimla as the capital city lies in the Himalayan region. There has been an increase in population and associated infrastructure development in the state of Himachal Pradesh (HP) in the last few decades. As per census 2011, the total population of HP is 6.8 million, which is about 12.81 % growth over census 2001. The state of HP comprising of twelve districts covers an area of about 55,673 sq. km. with the population density registered at 123 people per sq. km.

The conduct of the Hazard, Risk and Vulnerability Analysis (HRVA) and development of Risk Atlas is to help stakeholders make risk-based choices to address vulnerabilities, mitigate hazards and prepare for response to and recovery from hazard events. Risk-based means based on informed choices of alternate unwanted outcomes. In other words, stakeholders/communities make risk reduction choices based on the acceptability of consequences and the frequency of hazards. A given geographical area could be subjected to one of more hazards. The frequency and the intensity of these hazard events combined with the exposure and the capacity to absorb the shock determines the risk. A community may have been able to adjust to frequent hazards by undertaking risk reduction measures, however a low frequency high impact events can leave institutions and communities devastated. Given the limited time and resources, it is therefore necessary to understand what the greatest risk is and suitably undertake risk reduction action. HRVA also forms a critical part of the emergency response and preparedness programme. The local government is mandated to prepare disaster management plans. Assessment of the relative risk of occurrence and the potential impact on people, property and services in the jurisdictional area need to be understood for which the local authority is responsible.

This report is in line with the requirement of the initiative titled "GOI-UNDP Climate Risk Management in Urban Areas through Disaster Preparedness and Mitigation Project" with two main objectives to (a) reduce disaster risk in urban areas by enhancing institutional capacities to integrate climate risk reduction measures in development programmes as well as to undertake mitigation activities based on scientific analysis; and (b) enhance community capacities to manage climate risk in urban areas by enhancing their preparedness. Under the project, specific activities have been planned to attain key results such as: city disaster management plans, HRVA, training of communities to respond to disasters, action plans to strengthen early warning systems based on analytical studies, sectoral plans with key focus on mainstreaming of disaster risk reduction and climate change adaptation in development programmes and knowledge management. The geographical focus of the project covers eight multi-hazard cities in the country including Shimla.

This report focuses on Multi-Hazard Risk and Vulnerability Assessment (HRVA) of the city of Shimla in the state of Himachal Pradesh. Shimla once the summer capital of India and now the state capital of Himachal Pradesh is a growing city with a population of 169,758 (Shimla City, Census 2011) and 171,871 (Urban agglomeration, Census 2011). The city area is subject to a range of hazards, both natural and manmade. The rapidly urbanizing city is an economic hub and a symbol of development. The city, which was originally designed for a population of 25,000, now also attracts a large floating population of more than 120,000 during the peak tourist season. The city is also a regional employment hub and both national and international tourist attraction. Scarcity of land, booming economy and ineffective enforcement has resulted in unplanned growth and has precedence over safety. Some of the methods used for understanding and examining the ground situations are given below. Apart from these first hand observations, secondary data viz. Indian Meteorological Department (IMD) data, remote sensing data from Landsat, Bhuvan, etc. were used to carry out the secondary analysis and to arrive at results presented in this report.

- Rapid Visual Survey of the residential buildings to understand the vulnerability of the residences;
- Rapid Visual Survey of public buildings, government buildings, educational institutions, medical/health institutions, emergency buildings, police and paramilitary buildings, etc. to understand their dependability in case of an emergency;
- Socio Economic Survey of the households to understand their intrinsic vulnerability;

- Interviews with various stakeholders across the city to understand individual and institutional capacity;
- Transect walks across the city to examine the landslide susceptible areas and the sink/slide zones;
- Discussion with the tax department to understand the revenue generation capacity of the corporation through various taxes;

In the race to become a large agglomeration (and thereby receive more funds) city is extending its limits and newer areas are added into the city limits. Apart from the natural population growth, in-migration and floating population as tourists also add to the pressure on the existing service delivery. According to the Municipal Corporation of Shimla, on an average the floating population of the city is around 75,000 people each day. Apart from adding additional load on the existing infrastructure, these tourists also add to the chaos in the city by increasing the number of vehicles that ply on the narrow congested roads. Lack of experience to drive on the hilly roads and the indisciplined behaviour of the tourists that come with their individual vehicles add to the chaotic situation of the city. In areas like Sanjhauli, the local residents park their cars at a distance of more than 2kms from their residences and walk. From the settlement, a stretch of approximately 2kms on either side is filled with private cars parked along the road. Apart from the space constraints, natural resources like water and clean air supply are being constrained as well. Current water accessibility and time spent to collect water is 25mins on an average. Almost all the households, across all economic groups are storing water, which shows the insecurity in access to water. This shows the problem at the water distribution level. If we look at the sources level, many of the sources are already being disturbed, either for road widening, or filling up and accessing the land for other purposes (officially by the government departments) or for illegal construction activities.

According to the current survey alone, building vulnerability across the city is too high and when hazards like seismic and landslide are also considered, it spells catastrophe. About 65% of the existing buildings (of the 2,795 surveyed) are vulnerable owing to their age, type of construction and structural details. These are spread over all of the 25 wards. 1,348 households (that means 5,594 people) live in this vulnerable housing stock. Contradicting the popular myth that only the buildings with temporary materials are more vulnerable, the vulnerability of buildings was observed in all the building types – RCC buildings, brick masonry, wooden as well as temporary buildings. These vulnerable buildings, when respond to any of the hazards the safety of the people living in them becomes a matter of grave concern.

Access roads in the city are also very narrow and winding. Motorable roads are very limited. Lines of vehicles parked along the streets outside the neighbourhoods is a very common phenomena in Shimla. In terms of the accessibility, it is also observed that the emergency services also find it difficult to access the houses and vice versa. Detailed analysis of ambulance service and fire services has been carried out and many parts of the city are very difficult to be serviced.
The alarming part of the building vulnerability is the latest resolution passed by the Director, Town and Country Planning Organisation regarding the modifications in the prevailing building bylaws. Some of the obvious mistakes that have arisen out of the new resolution are: abolition of Single Umbrella Committee; earlier restricted area to be de-notified and merged with non-core area; empowering the architects to pass the building plans; abolition of building inspection squad; permitting construction on heritage buildings, etc. After analysing the existing building stock of the city, it has been realised that more than 65% of the existing buildings are in the class of high vulnerability. The amendments made to the building bye laws will further reduce the building safety and thereby the safety of the people living in those buildings.

Main objective of the city administration should be to reduce the risk to people and properties and at the same time, keep the economic growth intact. In this report we present the results of the hazards, vulnerabilities and risk faced by the city. After a detailed discussions with the stakeholders, a detailed set of recommendations will be filed.

The report is organised in sections. In the first part, hazards that are threatening Shimla are explained, later vulnerability of the city and the population is explained, this will be followed by an explaination of the the risk (damage and loss) and the institutional capacity to cope with the challenges.

1 Hazard Analysis

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Rainfall Analysis
Snowfall Analysis

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Forest Fire Hazard Assessment Equation
Summary

About

In this chapter, various hazards – geological, hydro-meteorological and fire hazards are assessed covering the city and its surrounding area. Use of state of the art technologies like remote sensing and datasets are put into use to analyse the extent and intensity of all these natural hazards.

1.1 Shimla - HydroMeteorological Analysis

Shimla is often referred to as the "Queen of Hills", a term coined by the British, is a very popular tourist destination. The city is located in the north-west Himalayas at an average altitude of 2,205 meter (7,234 ft). The city is spread on a ridge and its seven spurs. The city of Shimla, draped in evergreen glades of pine, deodar, oak and rhododendron, experiences pleasant summers and cold, snowy winters. The coordinates of Shimla are 31°6'12" North and 77°10'20" East. It has an area of 31.60 sq. km and stretches nearly 9.2 km from east to west.

Shimla falls under zone IV (high damage risk zone) as per the earthquake hazard zoning of India. There are no water-bodies near the main city and the closest river, Sutlej, is about 21 km away. Other rivers that flow through the Shimla district, although further from the city, are Giri, and Pabbar (both are tributaries of Yamuna).

Shimla features a subtropical highland climate under the Koppen climate classification. The climate in Shimla is predominantly cool during winters and moderately warm during summer. Temperatures typically range from -6°C to 31°C over the course of a year.

The average temperature during summer is between 19°C and 28°C and in winter between -1°C and 10°C. Monthly precipitation varies between 15mm in November to 434 mm in August. It is typically around 45 mm/month during winter and spring and around 175 mm in June as the monsoon approaches. The average total annual precipitation is 1,575 mm, which is much less than most other hill stations but still greatly heavier than the plains. Snowfall in the city, which has historically taken place in the month of December, has lately (over the last twenty years) been happening in January or early February every year. December, January and February are the months when Shimla experiences heavy chilling cold. During winters, the temperature frequently goes below freezing point. Snowfall is also very common during this period. Maximum temperature during winter is 8 -100C. Summer starts from April and lasts until June and during this season temperature fluctuates between 15°C to 28°C. In the next sections, detailed study of the climatic trends of Shimla city is discussed.

Image 1: A view of Shimla Suburb

1.1.1
Temperature Trend Analysis

Temperature trends were plotted for the years 1969-88 and 2008-14. The monthly minimum temperature distribution shows that the minimum temperature is decreasing over the period of 20 years whereas the maximum temperature is increasing. The graphs also show that the maximum and minimum temperatures are at their peaks during April to August.

Monthly maximum temperature variations for year 1969-88 and 2008-14 are shown in the Figure 1. The maximum daily temperature for the period 1969-88 shows a gradually increasing temperature trend in the area with minor exceptions in the months of August and October. The peak temperatures was observed during the months of April to August which is also seen in the monthly maximum temperature distribution for the years 2008-14. It is also observed that maximum monthly temperature has increased in recent years. As observed from the monthly minimum daily temperature variations for the years 1969-88 and 2008-14, the temperature at Shimla drops below zero in the months of January, February and December with the city experiencing lowest temperature in February.

However, the minimum temperature distribution (Figure 2) generated for the years 2008-14, indicates a change in the above mentioned trend, i.e. the temperature drops sub-zero only during the months of January and February. This observation supports the overall increase in temperature seen in the area. The lowest and highest daily average minimum temperatures are observed during the winter season (December to March) during the period 1969-2014 from the data. During most years, the lowest minimum temperatures recorded are around 0-4 degree Celcius during December, -5 to -1 degree Celcius during January, -4 to 0 degree Celcius during February and -2 to 2 degree Celcius in March. Such low temperatures are recorded on the clear nights after the snowfall days when western disturbances occur across the northern parts of the country.

Analysis of Extreme Temperature Days

Extreme temperature days were analysed for Shimla for three seasons, pre-monsoon (summer) spanning February to May, monsoon (rains) from June to September and post-monsoon (autumn and winter) from October to January. This analysis

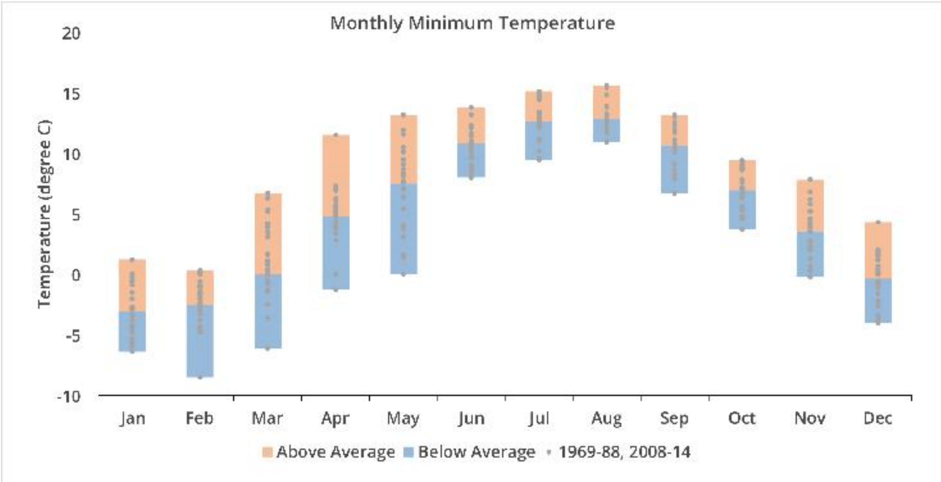


Figure 1: Monthly maximum temperature variations for the years 1969-88 and 2008-14

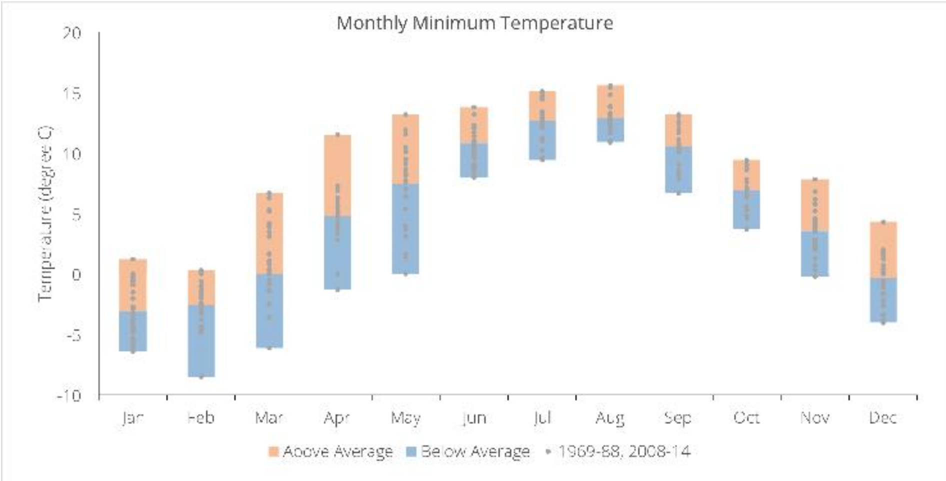


Figure 2: Monthly minimum temperature variations for the years 1969-88 and 2008-14

was carried out based on standard deviation. In the city of Shimla, the maximum temperature was never found to exceed 10 degree celcius more than average maximum temperature. However, during the winter months, lowest temperature fell 10 degree Celcius below average minimum temperature a few times (eleven instances from 1969-88 and 2008-14). Extreme temperature estimation based on standard deviation method has been performed for the three seasons mentioned above.

During the pre-monsoon summer season (Figure 3), it was observed that in 1969-88 period, around 8-10 days in each month the temperature was more than one standard deviation difference from the average maximum temperature. During the later period (2008-14), this number indicated an increase during considerably all four months. The average maximum temperature also rose by 2-3 degrees in the later years, particularly the moderate El Niño years of 2009-10. In short, a general rise in the temperature trend was observed during the 2008-14 span, where even the number of days when temperature increased by 2 standard deviations from the average maximum temperature recorded during previous years.

During the monsoonal season (Figure 4), a similar increase in temperature was observed. During all four monsoon months, the number of days with temperature more than one standard deviation than the average maximum temperature increased by almost 90% between the 1969-88 period and 2008-14 period.
The days with more than two standard deviation difference from average maximum temperature also increased considerably. The maximum number of hot days were observed during June and July in the later period. The average maximum temperature shows a slight increase during June and July in the later years while it stayed steady during August and September all through the years.

During the post-monsoonal winter months (Figure 5), the average maximum temperature in Shimla stayed almost steady during the study period. Though there was a significant increase in the number of days when the temperature increased by one standard deviation difference from the average maximum temperature, the overall increase in the temperature was not more than 1 degree Celcius in the region on an average. Significantly large temperature increases were observed in the months of October and November, during the 2009-10 El Niño period.

The later winter months of December and January showed the maximum variation in average maximum temperature during the years. Difference from average maximum temperature, the overall increase in the temperature has not been more than 1 degree C in the region on an average. Significantly large temperature increases were observed during the October and November months during the 2009-10 El Niño period. The later winter months of December and January show the maximum variation in average maximum temperature during the years.During the pre-monsoon summer season (Figure 6), the number of cold days were found to be more during the study period 1969-88 as compared to the years 2008-14. On an average 12, 8, 6 and 5 colder days occurred in February, March, April and May respectively. Number of days with moderate cold i.e. temperature one standard deviation less than the average minimum temperature, were significantly more from 1969-88 period. Number of very cold days i.e. the days with temperature two standard deviations lower than the average minimum temperature, were also more in the previous years (1969-88). In the years 2008-14 the very cold days rarely occured. Average minimum temperature greatly fluctuated over the study period. An overall increase in temperature can be observed from the analysis.

During the rainy season (Figure 7), a distinct increase in temperature can be observed. During all four monsoon months, the number of days with temperature less than one standard deviation than the average minimum temperature was much greater in the 1969-88 period; such cold days hardly occured in the later period (2008-14), and mostly in the month of June. The days with more than two standard deviation difference from the average minimum temperature also decreased considerably in the later years. The average minimum temperature had great fluctuation through the years but a significant increase of 2 degree Celcius was observed during all the monsoon months.During the post-monsoon or winter months (Figure 8), the average minimum temperature in the Shimla shows great fluctuation for the study period.

A significant increase in temperature of about 1 degree Celcius was observed. The later winter months of December and January show more number of days with temperature lower than one and two standard deviations than the average minimum temperature during the previous years 1969-88. The number of such cold days are considerably lower during the later period. Overall, though there has been an increase in the ambient temperatures, it can be safely said the city suffers from coldwaves during the winter months.

Figure 3: Analysis of hot days during pre-monsoon

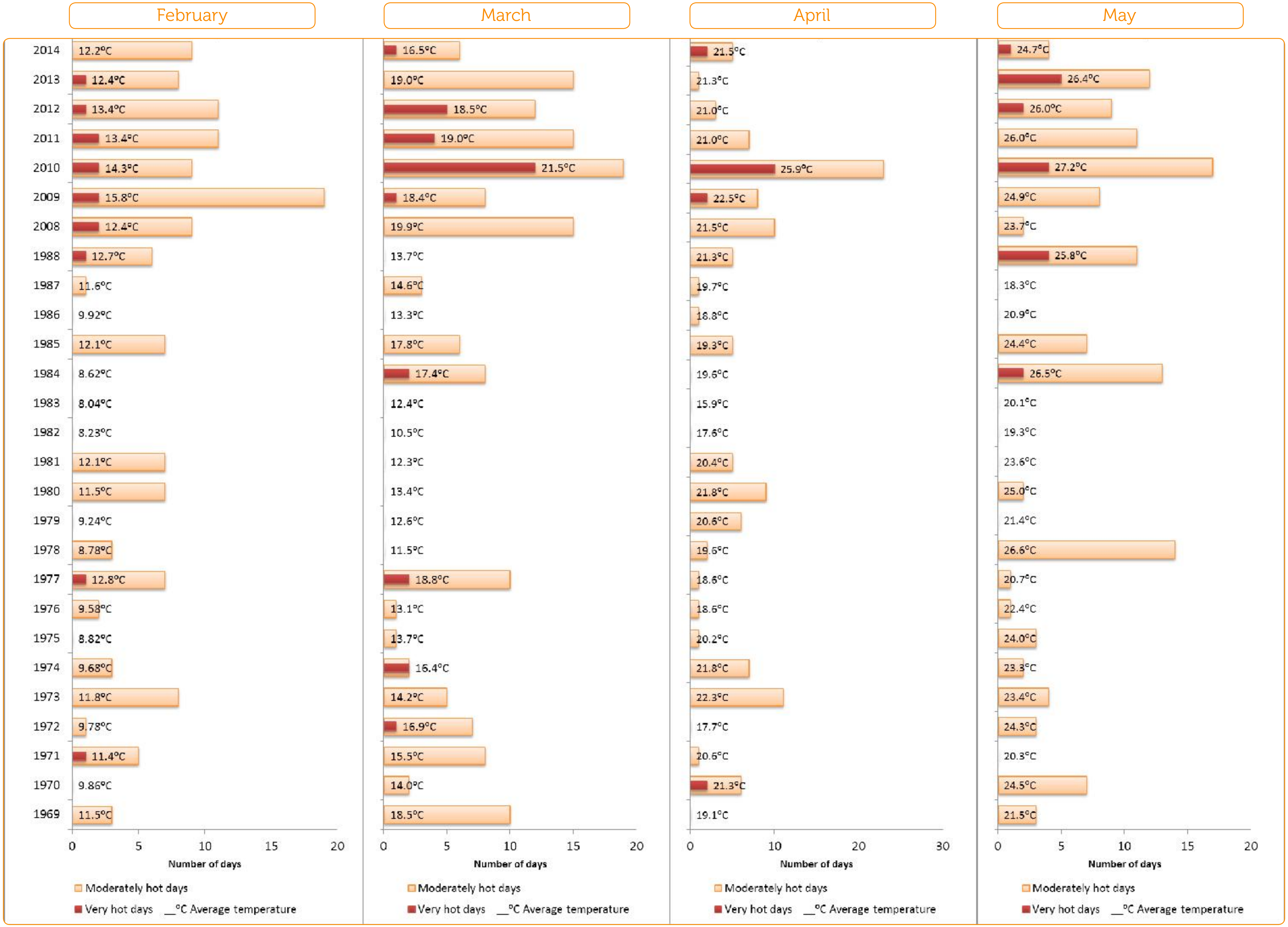


Figure 4: Analysis of hot days during monsoon

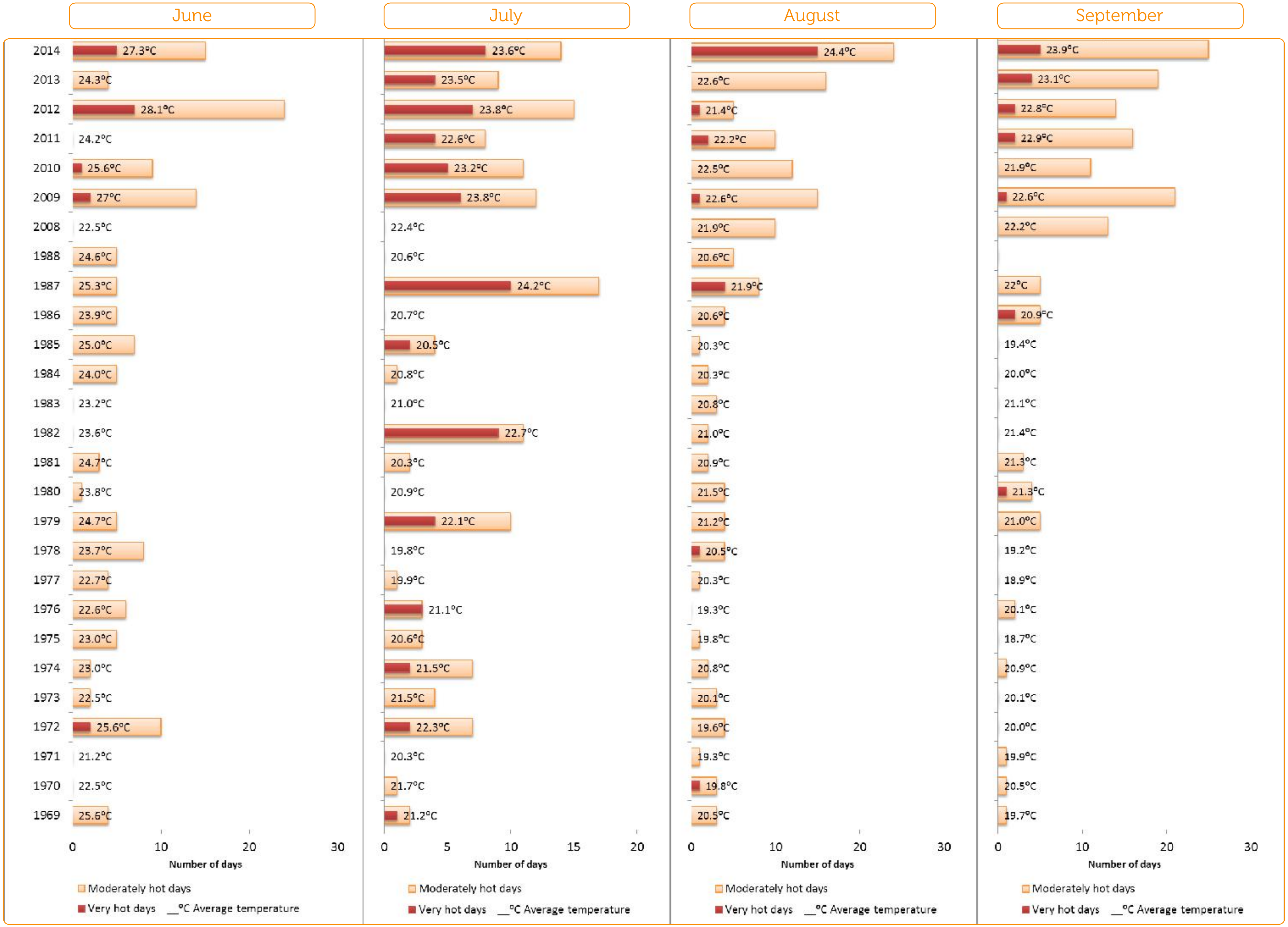


Figure 5: Analysis of hot days during post-monsoon

Figure 6: Analysis of cold days during pre-monsoon

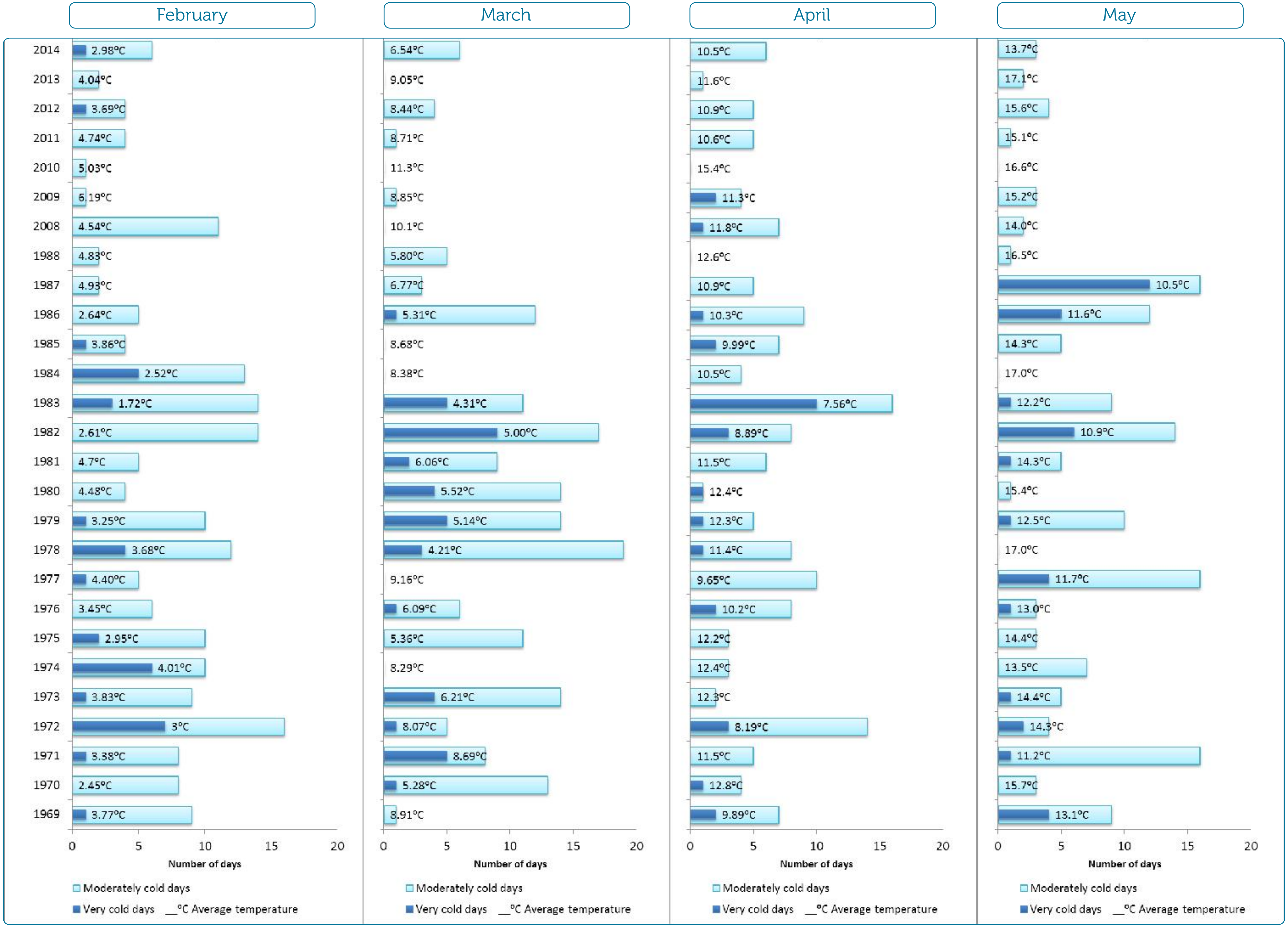


Figure 7: Analysis of cold days during monsoon

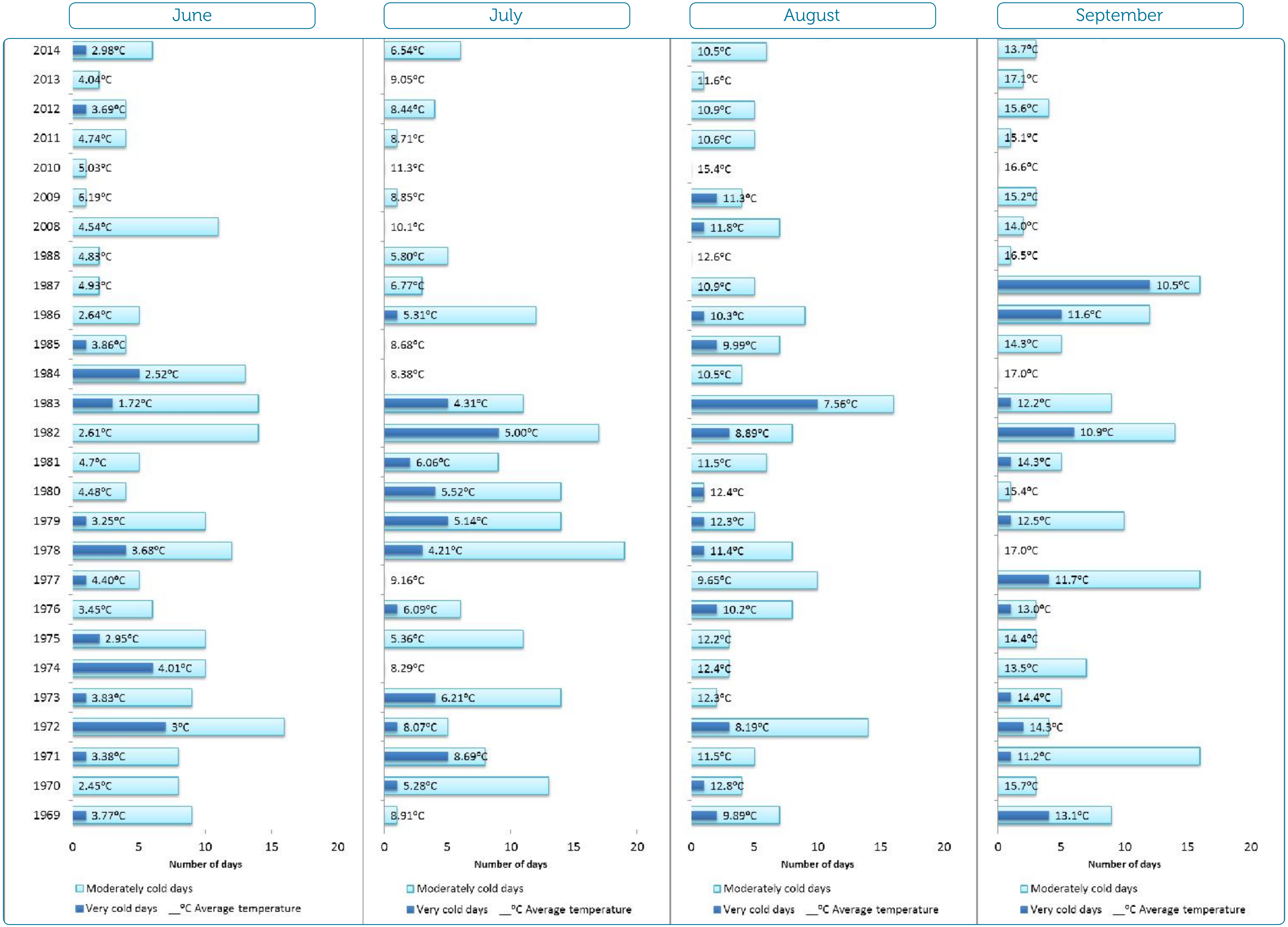
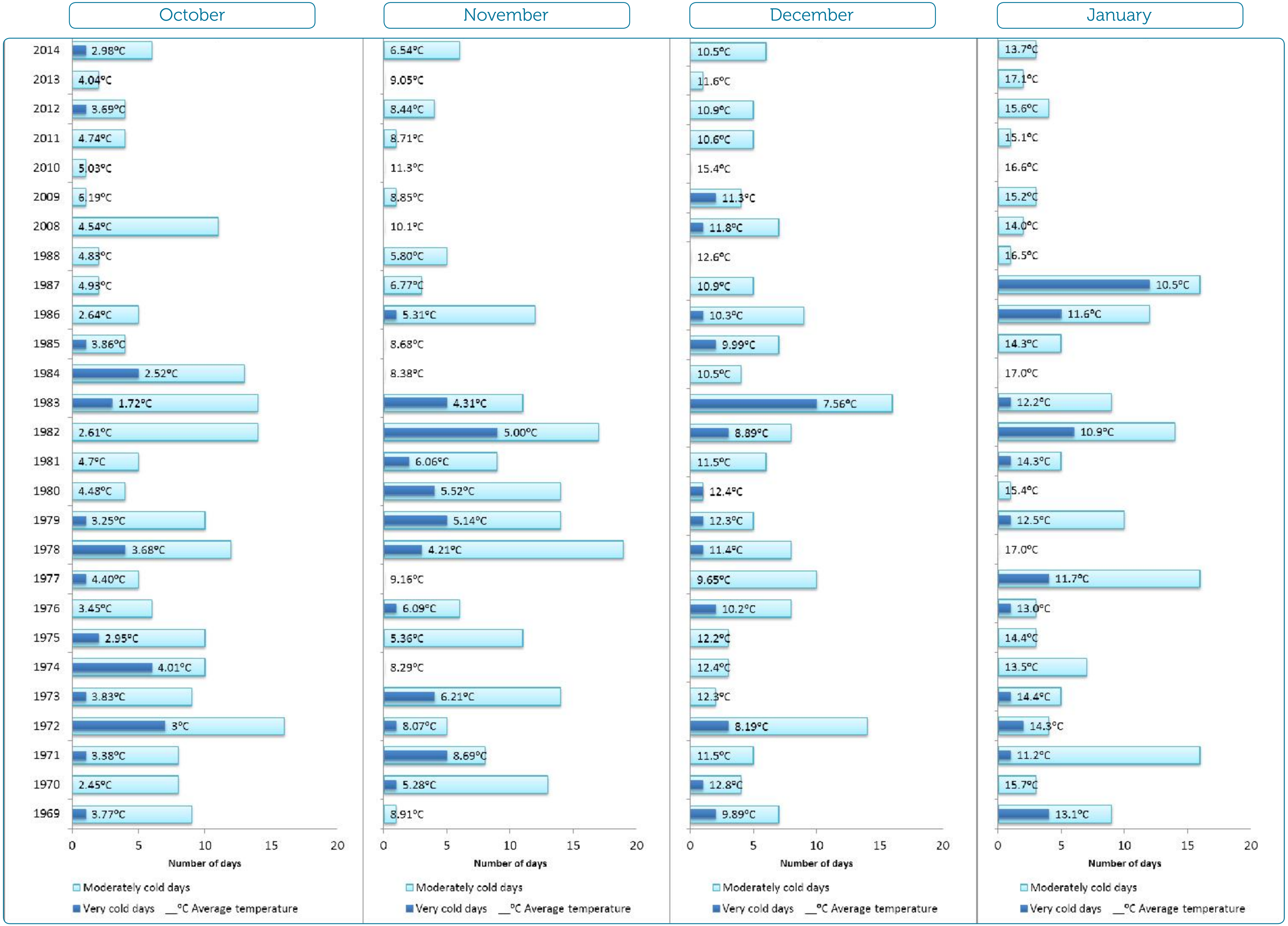


Figure 8: Analysis of cold days during post-monsoon

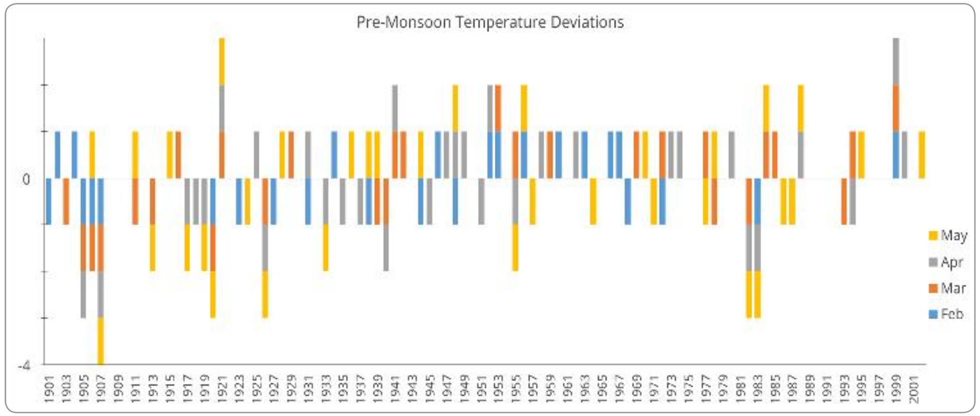


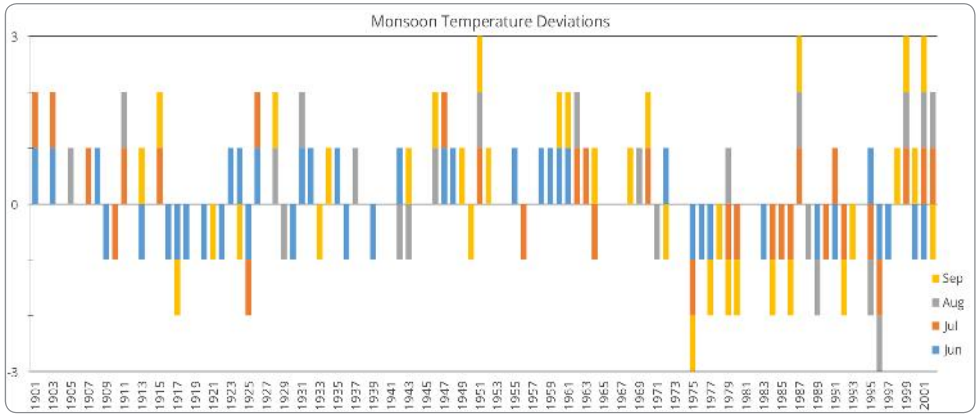
Monthly average temperature deviations for year 1901 to 2002

Temperature deviation analysis (Figures 9 and 10) is carried out to identify the months and years, which have experienced maximum temperature deviations as compared to the long term average. The data used for this purpose is the long term temperature data from 1901 to 2002 (data from India Water Portal). The long term average is calculated and the temperature values falling in the range of (average + standard deviation) and (average – standard deviation) are assumed to be within the normal natural climatic variation and hence not considered for moderate temperature deviation (moderate cold/ moderate hot days) analysis.

Similarly, the values falling outside the range of (average + 2 standard deviation) and (average – 2 standard deviation) are considered for extreme temperature deviation (very cold/ very hot days) analysis.

The months which are having deviations larger than the ranges mentioned above are plotted. The months above the central/zero line are those which have variation more than average + standard deviation (for moderate cold/ moderate hot days) and average + 2 standard deviation (for very cold/ very hot days). Similarly the months below the central/zero line are those which have variation more than





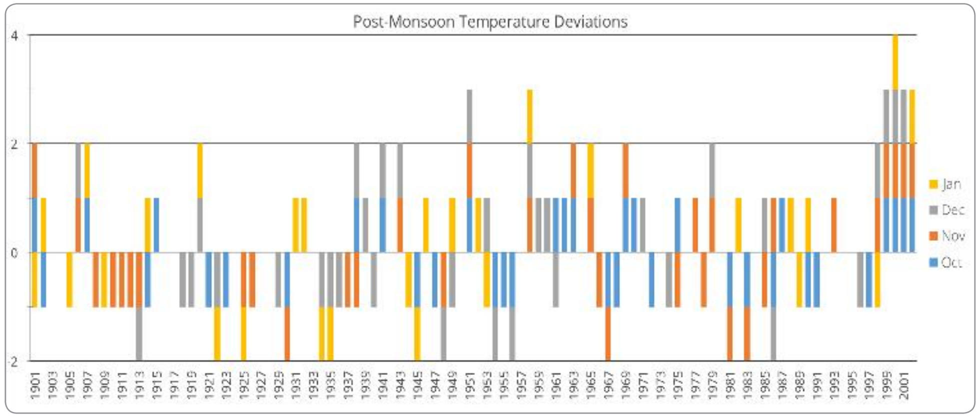


Figure 9 : Moderate temperature variation analysis

Top
During pre-monsoon season, the trends are greatly varying with 1907 being the year when there was a significant drop in temperature over the pre-monsoon months. In February and April temperature constantly varyied. The data of 1995 onwards is showing an increase in the overall pre-monsoon temperature.

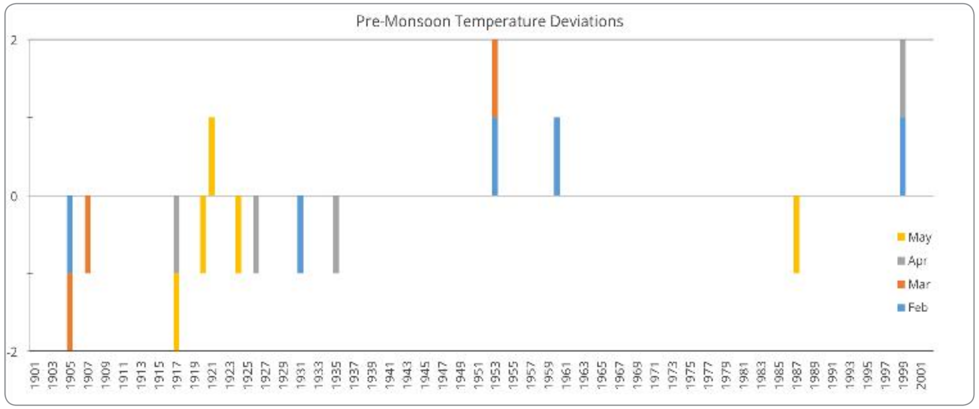
Middle
The temperature during the monsoon season was effectively increasing till 1969, but after that, the trends indicate an overall decrease in temperature. The month of June is the most fluctuating month in terms of temperature values recorded.

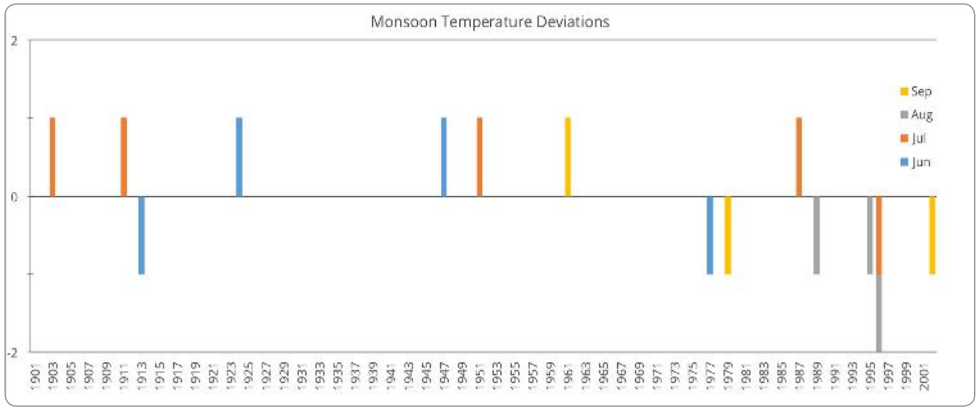
Bottom
During the post-monsoon season, temperature is fluctuating with the overall trend following the below average values. November, December and January were fluctuating the most till around 1952, after which the months of October, November and December are varying mostly towards the above average values.

average - standard deviation (for moderate cold/ moderate hot days) and average – 2 standard deviation (for very cold/ very hot days).The months which are having deviations larger than the ranges mentioned above are plotted.

The months above the central/zero line are those which have variation more than average + standard deviation (for moderate cold/ moderate hot days) and average + 2 standard deviation (for very cold/ very hot days).

Similarly the months below the central/zero line are those which have variation more than average - standard deviation (for moderate cold/ moderate hot days) and average – 2 standard deviation (for very cold/ very hot days).





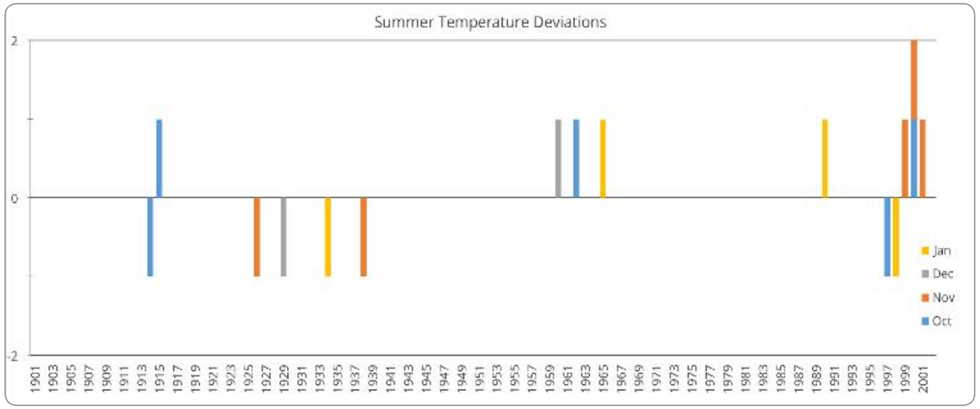


Figure 10: Severe temperature variation analysis

Top Left
The pre-monsoon temperature deviations were predominantly on the negative side i.e. below average temperature. April and May were the most fluctuating months during the period 1901 to 1935. After this period the intermittent extreme temperature deviations have occurred in 1953, 1960. 1987 and 2000 with February being the most fluctuating month.

Bottom Left
The monsoonal temperature deviations indicate that June and July are the most fluctuating months with the trend being predominantly higher than the 2 standard deviation values above average. 1996 was the only year where both July and August recorded very cold days.

Top Right
The post-monsoonal trend was mostly negative till 1939, after which the variations were not seen for longer span of time. After the year 1959 the positive trends have been observed with December being the least deviating month.

1.1.2 Rainfall Analysis

Rainfall in the study area increases from the middle of the month of June with the onset of pre-monsoon rainfall activity and the south-west monsoon usually sets in during the end of June. July and August are the rainiest months. Monsoon withdraws toward the end of the September. The rainfall decreases drastically from the month of the October with November having the lowest precipitation of the year, and again starts increasing from the month of December.

Rainfall Trend Analysis

To analyse the long-term and the seasonal rainfall trends over the study area, IMD station rainfall information has been utilized. Total yearly rainfall has been shown in Figure 11 for the years 1969-88 and 2008-14. The grey fringe indicates the "average ± σ" variations limit for rainfall data. A slight decreasing trend has been observed for long term accumulated yearly rainfall. It can be observed that average rainfall has increased so has the variation in the rainfall. It can be observed that the 1970's experienced more extreme rainfall highs and lows than the following years, until the recent years. Analysis of decadal change is slightly difficult because of the data gaps in the study area which spans over two decades (1988-2008). However, the rainfall variability has been very significant in the recent years. In the next few graphs, the variability of rainfall in the study area is elaborated.

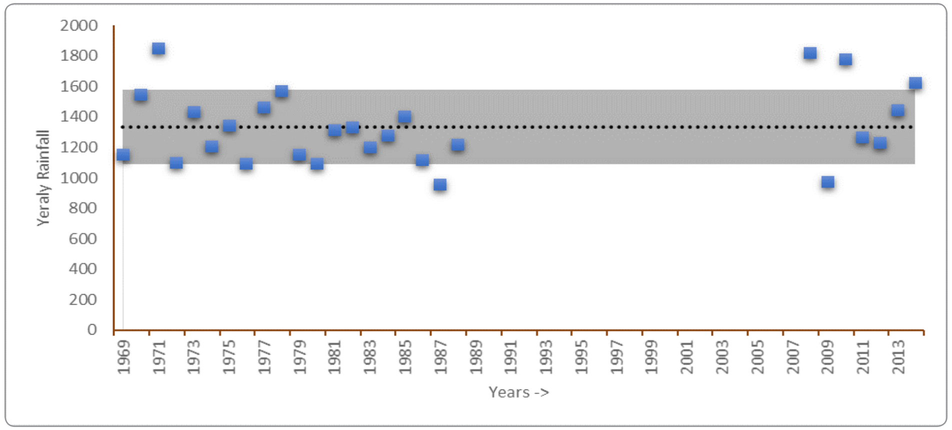


Figure 11: Total yearly rainfall

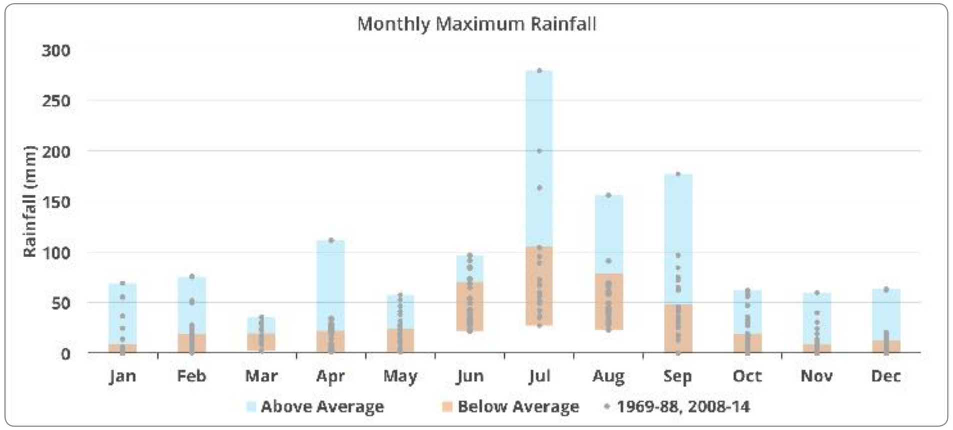


Figure 12 : Monthly maximum rainfall in a Day variations for the years 1969-88 and 2008-14

Figure 12 shows the maximum rainfall in a day in every month for the period of 1969-88 and 2008-14. As can be observed, extreme high daily rainfall were few and far between, with four significant extreme events in 1971-72, 1974 and 1984, all of which are moderate La Niña years (http://ggweather.com/enso/oni.htm). In-keeping with the ENS oscillation phenomenon, the periods between 1980-82 and once more 1986-88 were found to have been moderate El Niño years, when the study area has experienced rainfall deficiency and less moderate to heavy daily rainfall.

It can be observed from Figure 13 that the monsoonal onset has been shifting from the end of May in the 1960's to almost the beginning of July in the 1980's; the rain has been coming late and staying less. Thus, the total amount of precipitation in the study area during one monsoonal cycle has been steadily decreasing over the years.

In the recent years, the same trend of the onset of monsoons shifting towards post-monsoon season is observed (Figure 14). As seen from anomalies in the recent years the area has experienced more negative rainfall signifying poor monsoon than the long term normal.

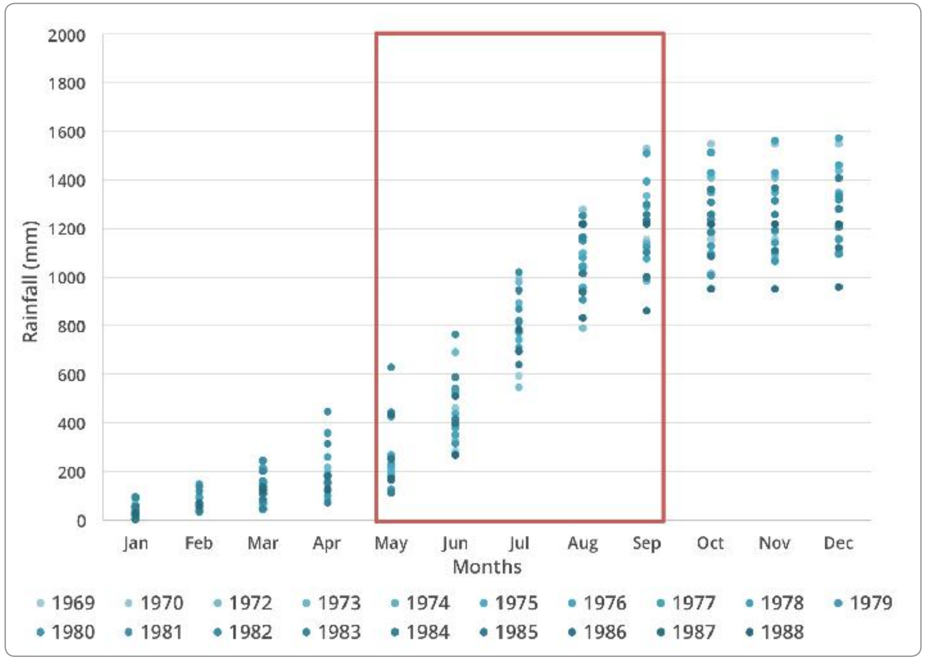


Figure 13: Cumulative rainfall graph (1969-88)

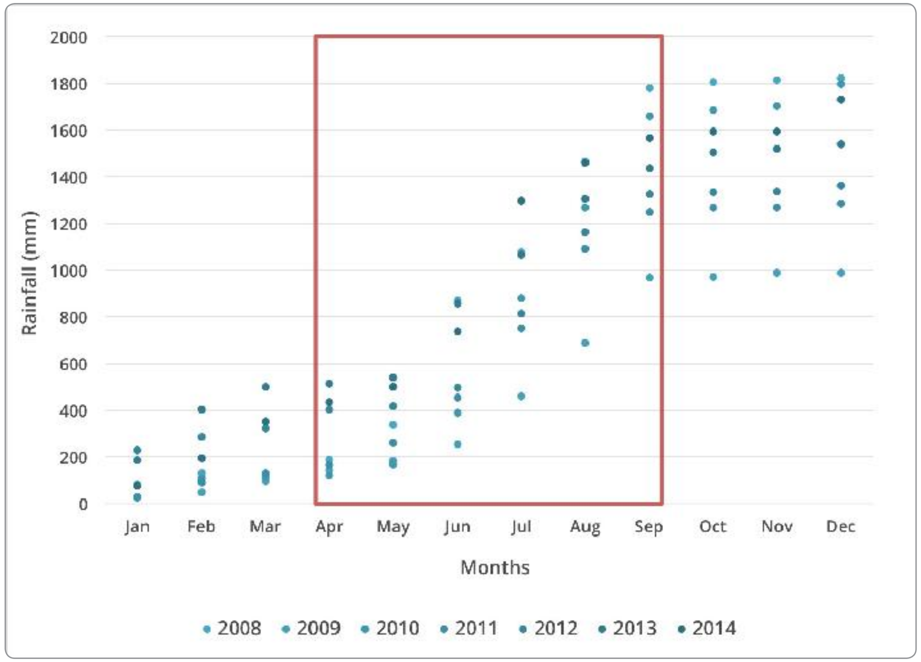


Figure 14: Total yearly rainfall Cumulative rainfall graph (2008-14)

Analysis of Extreme Rainfall Days

Extreme rainfall and rainfall days were analysed for Shimla for the three seasons, pre-monsoon (summer) spanning February to May, monsoon (rains) from June to September and post-monsoon (autumn and winter) from October to January. This analysis was carried out based on standard deviation in the data. The overall trend observed in the analysis was an increase in average rainfall during non-monsoon months. The rainfall pattern is fluctuating and tending towards extremes during El Niño and La Niña years. Figure 15 indicate the monthly trends in rainfall pattern for period 1969-88 and 2008-14.

During the pre-monsoon season, it was observed that except for the month of April, the average monthly rainfall was increasing over the study period. The year 1978 was showing significantly high average rainfall in February, March and April while it has lowest values in the month of May. The year 1978 was a weak El Niño year, which might have contributed to these rainfall variations. The year 2010 was a transition year from moderate El Niño to moderate La Niña, which can be observed through variation in rainfall.

The average rainfall and average + 1 standard deviation values were observed to be high in February and March during years 2013 and 2014. The year 1982, being a strong El Niño year, showed a drastic rise in rainfall variation during the month of April. The month of May has never experienced rainfall beyond twice standard deviation above average during the entire study period of 1969-88 and 2008-14. Overall the study area is showing an increase in the rainfall during pre-monsoon season.

Analysis of the rainy days during monsoon (Figure 16), indicates an increase in rainfall during the months of June and July, with a gradual decrease in the following months of August and September. The years 1971 and 2008 being moderate La Niña years, shows high average rainfall and heavy rain days in June. These years are also characterized by heavy rainfall and an increase in the number of rainfall days in the months of August and September. July witnesses wide variations in the rainfall data. Therefore, even though the values are high for average rainfall, number of days with heavy to extreme rainfall, are very less.

The year 1988 shows significantly high values in the months of July and August. However, no values have been indicated for June and September (1988) due to the values being well within acceptable range and data unavailability, respectively. According to the review of literature, 1988 being a strong La Niña year, explains the high rainfall values. The trend clearly indicates heavy rainfall in the months of June and July, with a gradual decline over time during August and September.

To understand and analyse the trends and variability in the post-monsoon season, rainfall and rainfall days have been plotted in Figure 17. The year 1985 is having highest extreme rainfall days during October and December. During October the highest value of average rainfall is seen in 1987.

The years 1985 and 1987 were weak La Niña and moderate El Niño years respectively. November had the highest average rainfall in the year 1981 for the study period under consideration. The year 2010 has peaks in average rainfall for all the post-monsoon months. The year 1972 is having significantly high extreme rainfall days for all months. This might be due to the fact that it was a strong El Niño year. Overall the average rainfall for the post-monsoon was decreasing slightly from 1969-88 with a few exceptional peaks in between. The average rainfall is slowly and steadily increasing during the years 2008-14.

Figure 15: Analysis of rain days during pre-monsoon

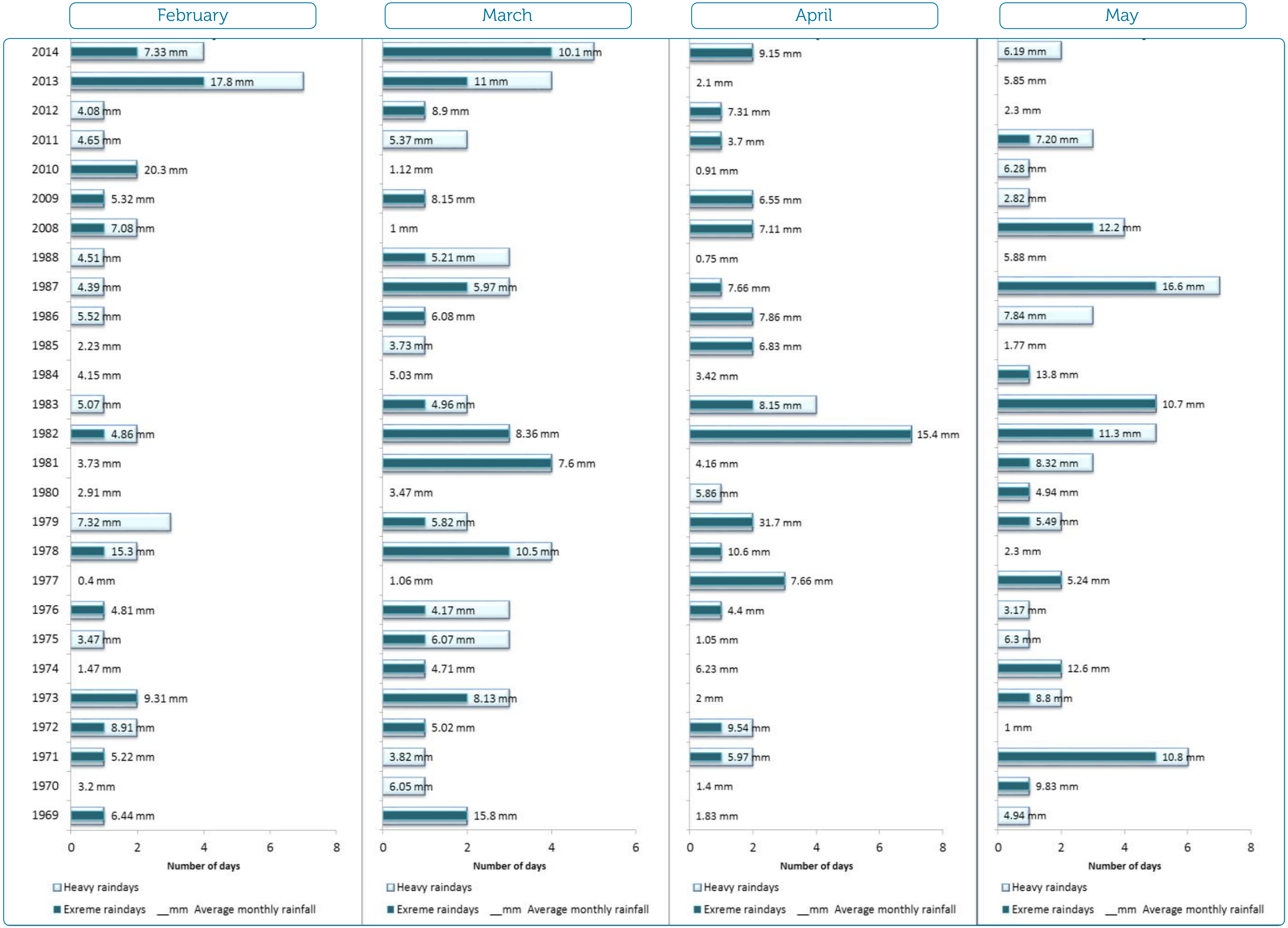


Figure 16: Analysis of rain days during monsoon

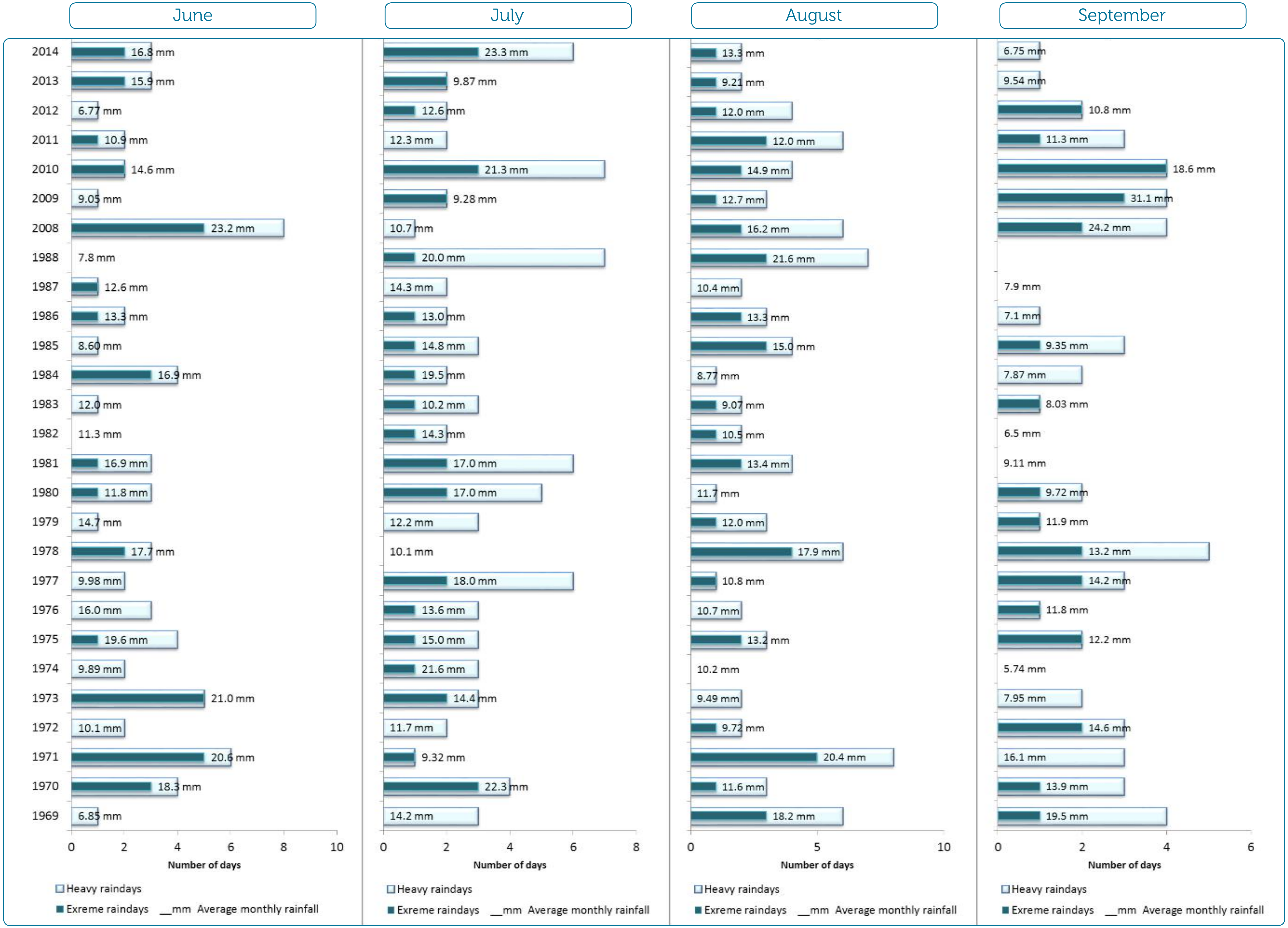
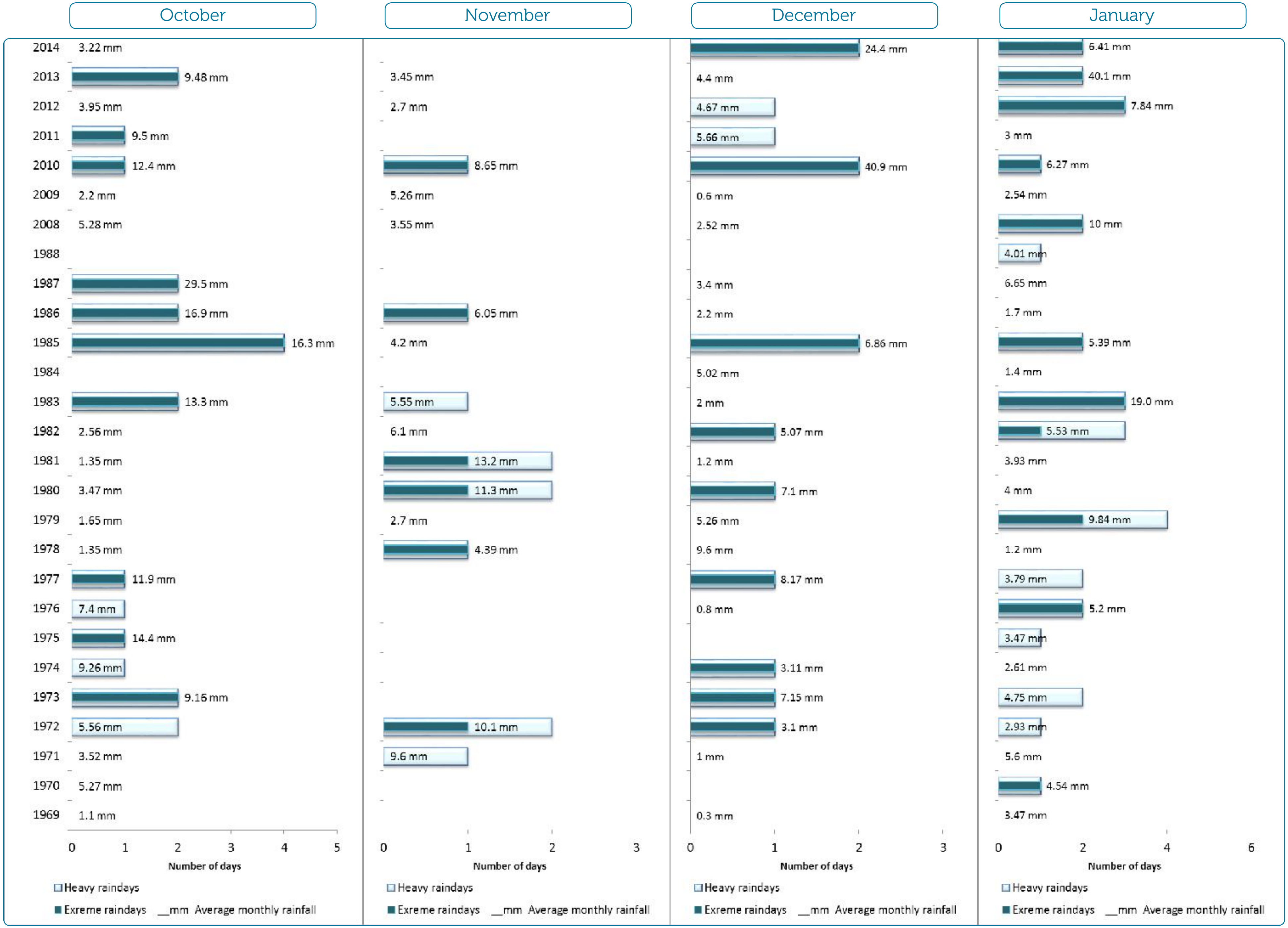


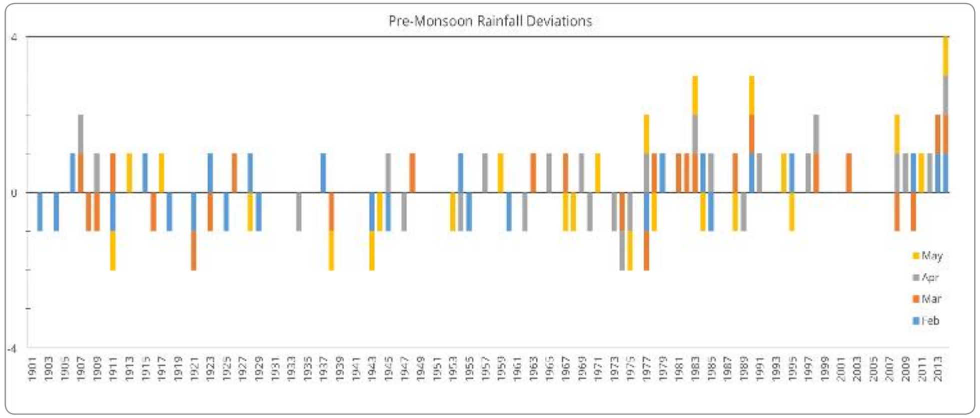
Figure 17: Analysis of rain days during post-monsoon

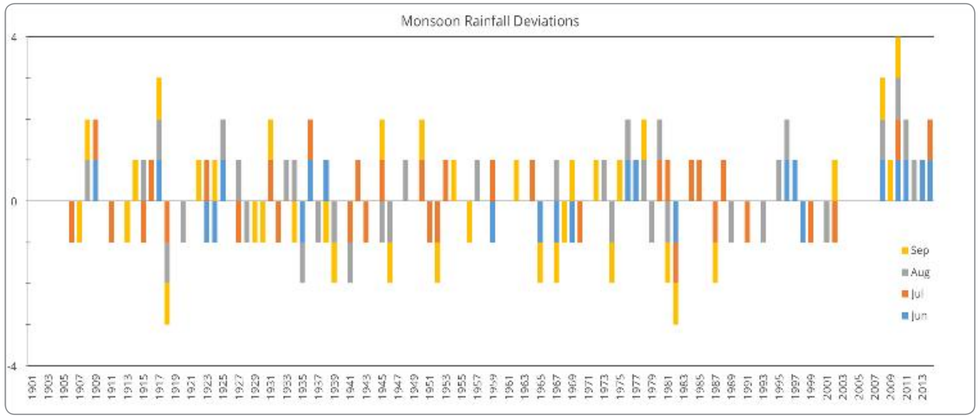


1.1.2.3. Monthly average rainfall deviations for year 1901 to 2014

Rainfall deviation analysis (Figure 18 and 19) is carried out to identify the months and years which have experienced maximum rainfall deviations as compared to the long term average. The data used for this purpose is the long term rainfall data from 1901-14 with a data gap from 2003 to 2007 (data from India Water Portal and IMD). The long term average is calculated and the rainfall values falling in the range of (average + standard deviation) and (average – standard deviation) are assumed to be within the normal natural climatic variation and hence not considered for heavy rainfall analysis.

Similarly, the values falling outside the range of (average + 2 standard deviation) and (average – 2 standard deviation) are considered for extreme rainfall analysis. The months which are having deviations larger than the ranges mentioned above are plotted. The months above the central/zero line are those which have variation more than average + standard deviation (for heavy rainfall analysis) and average + 2 standard deviation (for extreme rainfall analysis). Similarly the months below the central/zero line are those which have variation more than average - standard deviation (for heavy rainfall analysis) and average – 2 standard deviation (for extreme rainfall analysis).





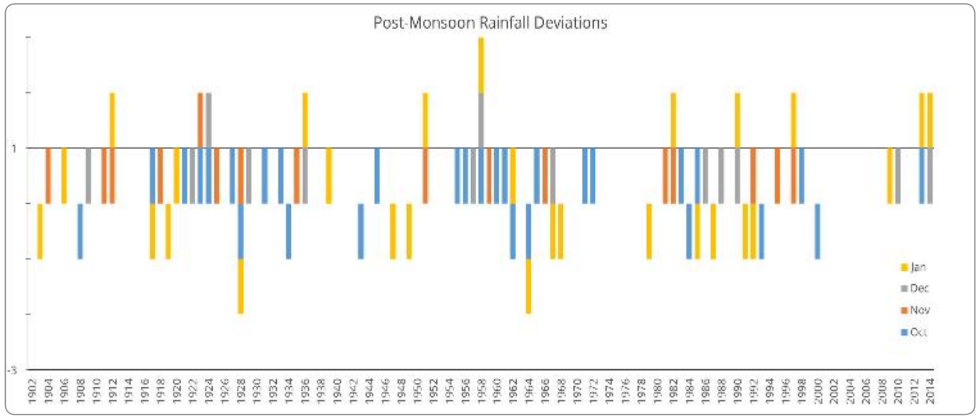
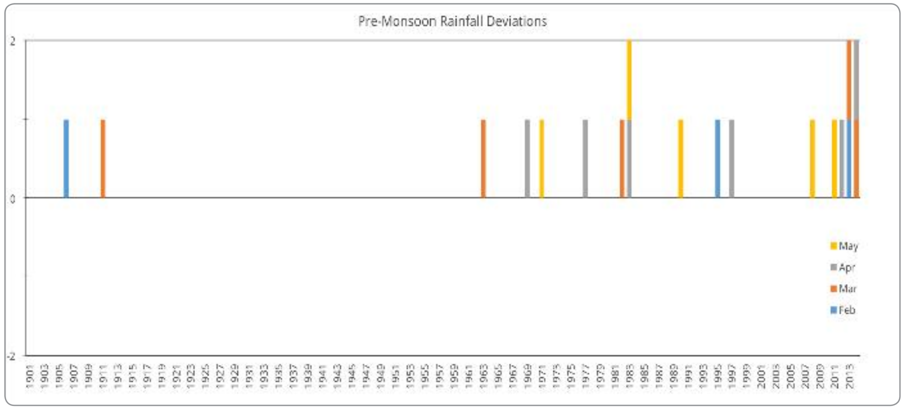


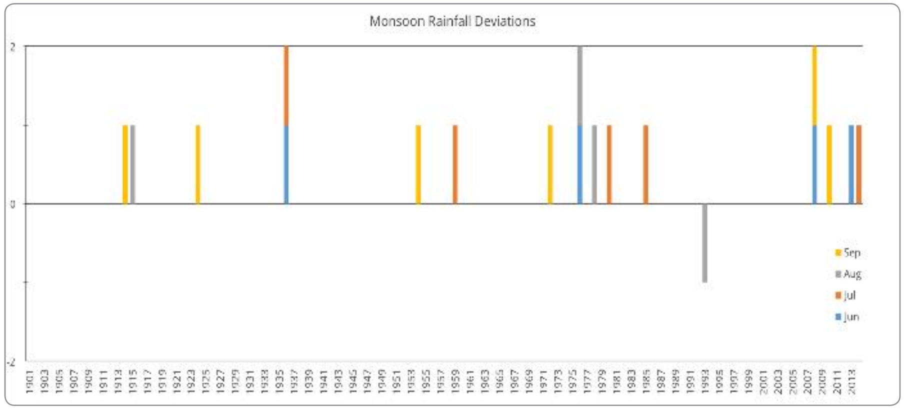
Figure 18: Moderate rainfall variation analysis

Top
The pre-monsoon season heavy rainfall deviations indicate that till 1977 the rainfall was decreasing steadily especially in the months of February and May. From 1977 till 2002, it can be seen that there is increase in the positive heavy rainfall deviations, which is continued in the period from 2008-14 too.

Middle
The months of July and September have frequent heavy rainfall deviation both positive and negative. The deviations are seen to be following a decreasing trend till 2002. From the year 2008 onwards heavy rainfall deviations are observed especially in the months of June and August.

Bottom
Post-monsoonal trends indicate that there is negative trend in the heavy rainfall deviations. At the same time the month of January is steadily experiencing positive trend in the heavy rainfall deviation. October is having mostly negative heavy rainfall deviation throughout the study period.





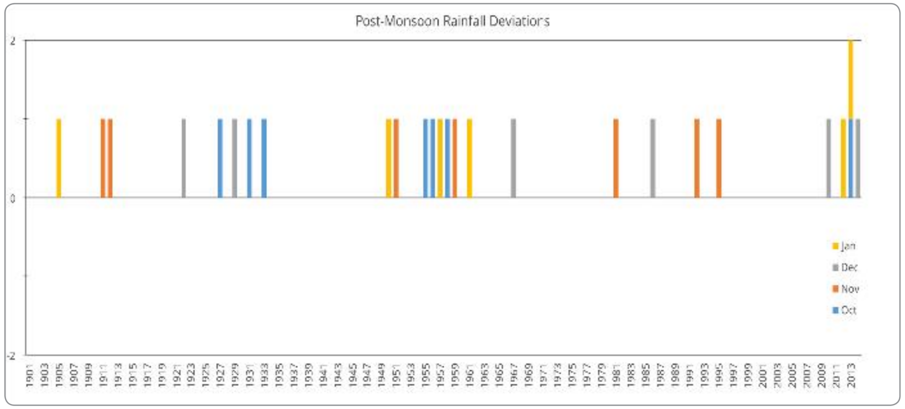


Figure 19 : Severe rainfall variation analysis

Top
During pre-monsoon season, extreme rainfall deviation was observed in 1906 (February), 1911 (March) and then was within normal range till 1963 where extreme rainfall deviation was observed in March. Since 1963, there has been an increase in extreme rainfall deviation till date, especially in the months of April and May.

Middle
Over the years there has been a positive trend in the extreme rainfall deviations except the year 1993 (August). In 2008, both June and September experience extreme rainfall deviation.

Bottom
The extreme rainfall deviations though less in frequency are spread throughout the study period and have occurred more frequently in the recent past.

1.1.3 Snowfall Analysis

The city of Shimla generally experiences snowfall from the second fortnight of December to the first fort night of March.According to the previous study by Tyagi et al., 2011, Average snowfall for the months of December, January, February and March for the period of 1990-2008 were 7, 38, 39 and 7 cm respectively.

However, recent data shows that the amount of snowfall during the month of March has decreased drastically with the notable exception of the year 2014 (Figure 20). In comparison to previous studies, the month of January continues to receive the maximum amount of snowfall over the years (2008-14).

Number of snow days from the year 2008-14 show distinct inter-year variability. Previous study showed significant decreasing trends in monthly snowfall days from 1971 to 2008 (Tyagi et al., 2011). The present study however finds that both 2012 and 2014 showed significant inter-annual fluctuations in the total number of snow days, particularly for the months of January and February (Figure 21). Average monthly snowfall was calculated using snowfall data of 20 winter seasons (i.e. from 1990-91 to 2010-2011) recorded at the IMD, Shimla. Monthly highest snowfall was observed to be 205 cm in December 1990, 109 cm during January 1993, 113 cm during February 2007 and 63 cm in the March 1998. Highest snowfall recorded in a day was 104.8 cm on 31 December 1990; 57.7 cm 23rd January, 2004; 54.1 cm on 12 February, 2002 and 62.8cm on 13 March, 1998.

Percentage distribution of the snowfall with respect to the total precipitation during the month of December, January, February and March is 7%, 42%, 43% and 7% respectively (Figure 22). The trend observed in the seasonal snowfall days from 1971 to 2010 show a significant decrease. This decrease in the snowfall days is probably due to rise in temperature. (Tyagi et al., 2011)

A "heat wave" is defined as a sequence of 3 or more days in which the daily maximum temperature is above the 90th percentile of daily maximum temperature during the given period. (Russo, 2015) Figure 23 depicts the trends in the heat wave occurrences over the given period. A heat wave analysis done for Shimla indicates that the consecutive years 2010, 2011 and 2012 had maximum number of heat wave events during the given period of 1969 to 2014.

These three years were transition La Nina years with the shift being from moderate to weak La Nina effect. The months with maximum occurrence of heat wave events were March and April during the years 1969 to 1988. During the years 2008 to 2014, the heat wave events have been occurring frequently in the months of February and March. Similarly a "cold wave" is considered as sequence of 3 or more days in which the daily minimum temperature is below the 10th percentile of daily minimum temperature during the given period. The graph shown below illustrates the trends in the cold wave occurrences over the given period.

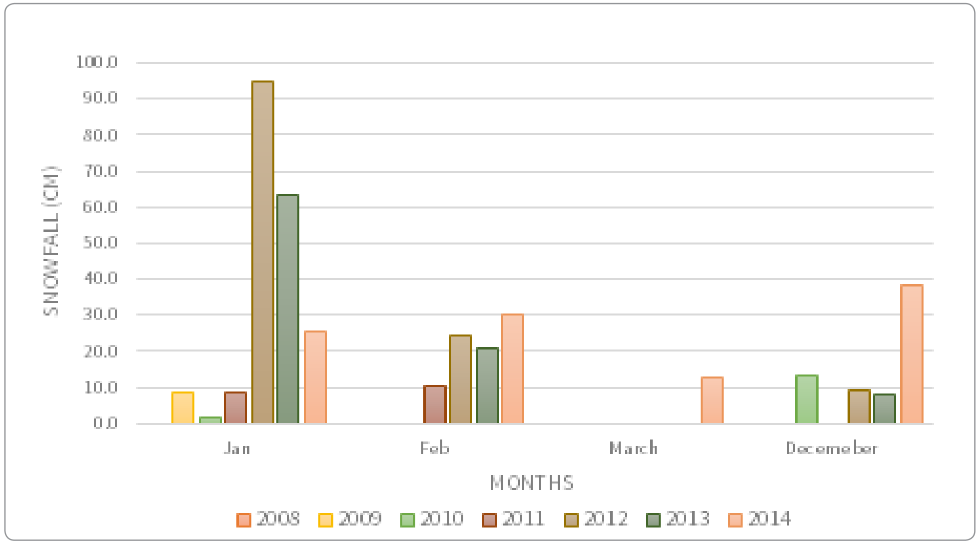


Figure 20: Snowfall volume (cm) from 2008-14 for the months of JFMD

A cold wave analysis (Figure 24) done for Shimla indicates that the years 1971, 1984 and 1985 had maximum number of cold wave events during the given period of 1969 to 2014. These three years were transition La Nina years with the shift being from moderate to weak La Nina effect. The months with maximum occurrence of cold wave events are November and December. During the recent years i.e. from 2008 to 2014, the occurrence of cold wave events has gone down drastically. The analyses of heat waves and cold waves is indicative of an overall increase in temperature in the recent years.

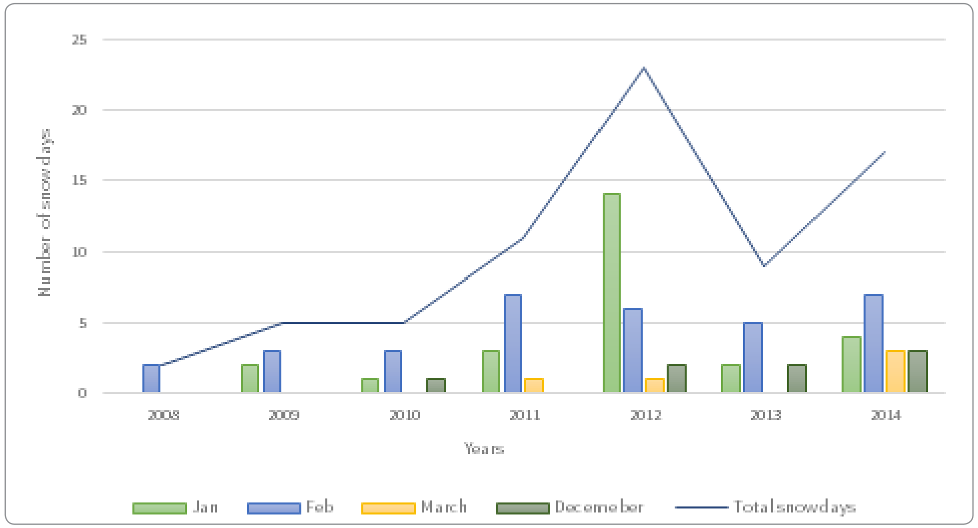


Figure 21: Snowfall volume (cm) from 2008-14 for the months of JFMD

Note: The overlaid blue line depicts the total number of snow days for each year.

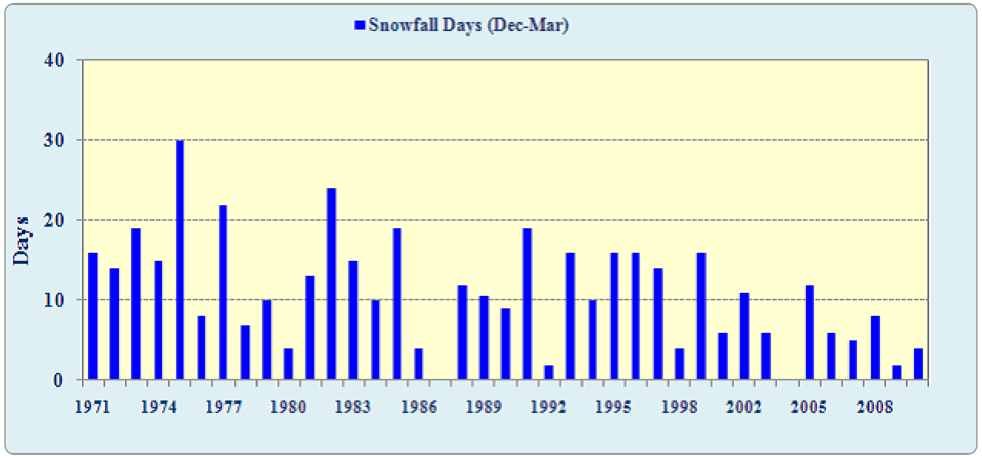


Figure 22: Snowfall days in Shimla during the winter season (Dec-Mar)

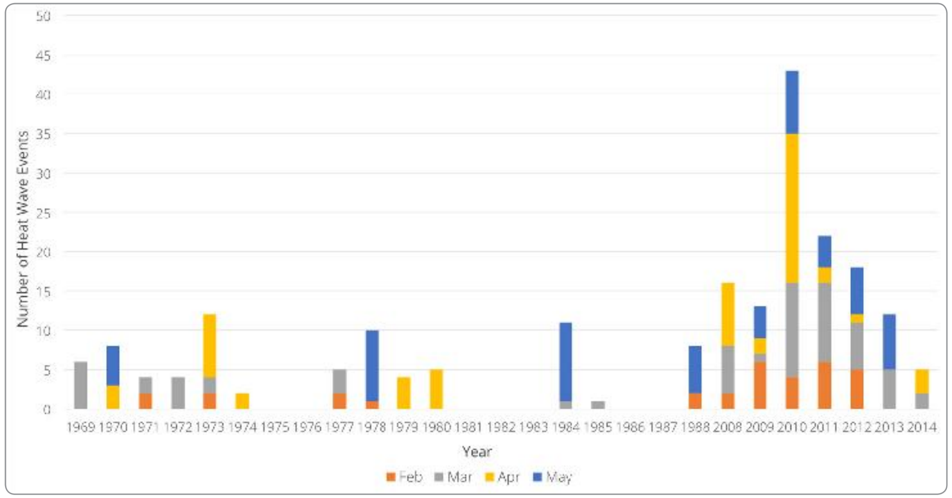


Figure 23: Heat wave occurences

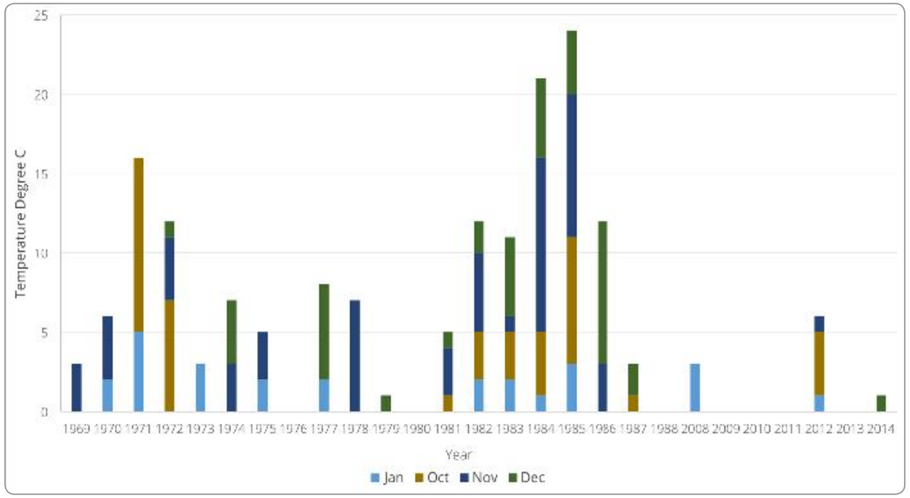


Figure 24: Cold wave occurences

1.2 Seismic Hazard Analysis

The Indian standard code of practice for earthquake resistant design of structures, IS 1893 (2002), has identified seven districts of HP in zone of most severe (zone V) seismic hazard with the design peak ground acceleration (PGA) as 0.36g. The remaining five districts lie in the zone of high seismic hazard (zone IV) with design PGA as 0.24g. This region has experienced strong earthquakes in the past. The 1905 Kangra earthquake (Mw 7.8) caused severe damage in Kangra and Dharmashala region of HP. Apart from this event, damages have been reported during the 1975 event (Mw 6.8), 1991 Uttarkashi earthquake (Mw 6.8) and 1999 Chamoli (Mw 6.5) earthquake. In the present times, with sharp increase in population and urbanization, similar event would cause far more damage and destruction. Moreover, the numerous planned developments that has been initiated in many of the fast growing towns in this region, needs to include a seismologically reliable planning and designing element.

Due to continuous efforts by different researchers, there is considerable improvement in our knowledge about seismo-tectonic characterization and relevant data in India. For instance, Geological Survey of India (GSI) has compiled and integrated all available data on geological, geophysical and seismological attributes for the entire country and has brought out the Seismotectonic Atlas of India and its Environs (GSI 2000). Similarly, paleoseismic investigations and identification of historical events (Oldham 1883; Iyengar et al.1999) helps us to build a robust earthquake catalogue. Further, important information on the quality factors of different regions of India are available (National Disaster Managemnt Authority (NDMA) 2011). By integrating all the above scientific information, it is possible to carry out probabilistic seismic hazard analysis (PSHA) of HP. Mapping of the PSHA results will be useful to engineers, planners and to agencies interested in disaster mitigation.

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1.2.1 Earthquake Catalogue

The first step in PSHA is to develop seismicity database of the region. A comprehensive database of location, date and magnitude of past earthquakes is required to understand the seismic status of the region. In the past several investigators attempted to prepare earthquake catalogues for the Indian subcontinent. Notable past efforts in collecting earthquake data for India are by Oldham (1883), Chandra (1977, 1992); Bapat et al. (1983), Guha and Basu (1993), Iyengar et al. (1999), Rao (2005), and Raghukanth (2011). Oldham was perhaps of the earliest to create an earthquake catalogue for India. A list of significant Indian earthquakes up to 1869 was prepared by Oldham (1883). Quittmeyer and Jacob (1979) prepared a list of Himalayan earthquakes.

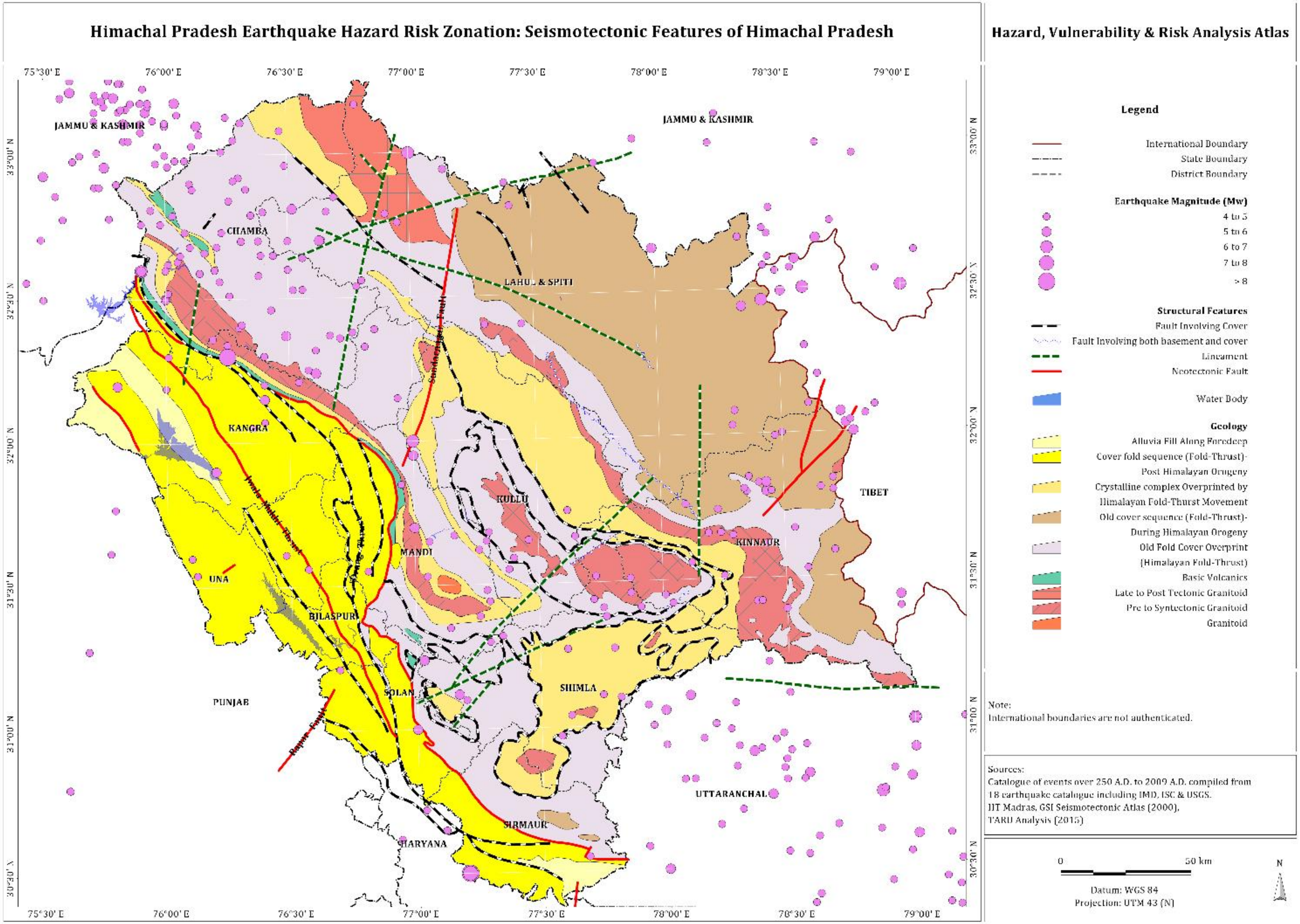
The catalogue of Bapat et al. (1983) lists about 40 earthquakes in India and its neighbouring region prior to 1800 AD. Chandra (1992) compiled 711 events from the Himalayan region for the period 1505-1986. Iyengar et al. (1999) carried out an intensive search of ancient Indian literature for earthquake related information. They identified 38 damaging events in India in the medieval period. Ambraseys and Jackson (2003) identified seven historical events with estimated magnitudes Mw >7 in North India and Tibet. Rao (2005) reviewed several earthquake catalogues prepared for the Indian region and identified fifty important events from 1250 BC to 1963 AD. Pakistan Meteorological Department compiled a list of 58 historical events during AD 25-1905 that occurred in Kashmir and in Pakistan. Ambraseys and Bilham (2009) searched Persian historical documents, British and French Consular reports to identify 52 earthquakes in Afghanistan for the period AD 734-2004. Apart from these historical events, paleo-seismic investigations have been carried out by several investigators to identify the location, time and size of the prehistoric events. These events can be used to supplement historical and instrumental data (McCalpin 2009).

Since the recurrence intervals of large and great earthquakes exceed the duration of instrumental and historical records, prehistoric events identified by paleo-seismic investigations would be valuable in building up the earthquake catalogue. Kumar et al. (2001) carried out paleo-seismic investigations on the Himalayan frontal thrust (HFT) and obtained evidences for a great earthquake (Mw >8) in 260 AD and two major events (Mw >7) in 1294 AD and 1423 A.D near Chandigarh. Investigations by Malik et al. (2003) support the identification of the above three HFT events. Lave et al. (2005) obtained geological evidences for an earthquake of magnitude (Mw >8.5) on HFT c 1100 AD in fareast Nepal. The most accurate and complete information on instrumental earthquakes for India is from permanent global seismic network observations operated by International Seismological Centre (ISC). This data from 1922 to till date is available in the ISC website (http://www.isc.ac.uk/). The US Geological Survey (USGS) (http://neic.usgs.gov/) website also contains information on location, date, origin, time and magnitude. This is considered to be one of the reliable data repositories since 1973. Apart from these global databases, the IMD data base is comprised of historically and instrumentally recorded earthquakes.

Only local magnitude ML is assigned to the recorded earthquakes. Recently for the PSHA work of NDMA, Iyengar and Raghukanth have assembled an all India catalogue containing all known events of magnitude Mw ≥ 4 for the region (20- 400 N; 610-1000 E). A catalogue containing events of magnitude Mw ≥ 4 for the region has been compiled from all the above sources. Epicenters of these earthquakes are plotted in the figure below. Map 1 immediately provides a synoptic view of the spatial pattern of the seismicity in the controlling region. As per the available data, Himalayan and Indo-Gangetic seismic belt influences maximally the seismic hazard at HP.

1.2.2 Tectonic Setting of the Region

Estimation of seismic hazard requires identification of geological and tectonic zones in the 500 km region around the site. The generalized tectonic map of Himachal Pradesh is shown in Map 1. Indian subcontinent can be divided into three physiographic divisions namely the Himalayas, Indo-Gangetic plains and peninsular India (Valdiya 2010). Of these three divisions, Himalaya is seismically the most active region and HP lies in this region. The Himalayas are 2500 km long with the width varying from 250 to 300 km and runs from Kashmir in the north-west to Arunachal Pradesh in the north-east. Himalayan arc is convex southwards with Hazara syntaxis marking the western extremity and the Siang syntaxis marking the eastern extremity. The Himalayan arc meets Pamir–Hindukush region and the Burmese arc at its western and the eastern ends, respectively.



Map 1: Himachal Pradesh & its Environs - Main Earthquake Events

The Himalayas is believed to have been formed 50–60 million years ago due to the collision of Indian plate with Eurasian plate along the Indus Tsangpo Suture (ITS). Due to this collision, there is a continuous build-up of strain which makes Himalayas seismically active. This collision gives rise to the formation of active faults like the Trans Himadri fault (THF), main central thrust (MCT), the main boundary thrust (MBT) and the main frontal thrust (MFT). These faults run along the entire length of the Himalayas.

The MCT dips 300 to 500 northwards and separates the greater Himalaya from lesser Himalaya. The MBT dips 300 to 500 northwards and separates the lesser Himalaya and outer Himalaya (Kayal 2008). The MFT separates the outer Himalaya from the Indo-Gangetic plain. Apart from these major faults, there are a number of faults present in this region. The thrust faults in the Himalaya divide the region into four geological zones namely the Siwalik range, lesser Himalaya, greater Himalaya and Tethys domain. The Siwalik ranges which defines the southern boundary of the Himalayas contain the sediments deposited by ancient Himalayan rivers.

The Himalayas is believed to have been formed 50–60 million years ago due to the collision of Indian plate with Eurasian plate along the Indus Tsangpo Suture (ITS). Due to this collision, there is a continuous build-up of strain which makes Himalayas seismically active. This collision gives rise to the formation of active faults that faults run along the entire length of the Himalayas.

The elevation of Siwalik ranges lies in between 0.25 km to 0.8 km. The rock formations in lesser Himalaya zone are typically upper tertiary molassic sedimentary deposits. The lesser Himalaya which lies in between MBT and MCT consists of mostly palezoic sedimentary rocks. The average elevation in lesser Himalaya is 2.5 km. The greater Himalaya which is the most northerly sub-province comprises of crystalline metamorphic and igneous rocks. The average elevation in this geological zone is about 5 km. The formations are highly folded and thrusted in the areas north of the MBT.

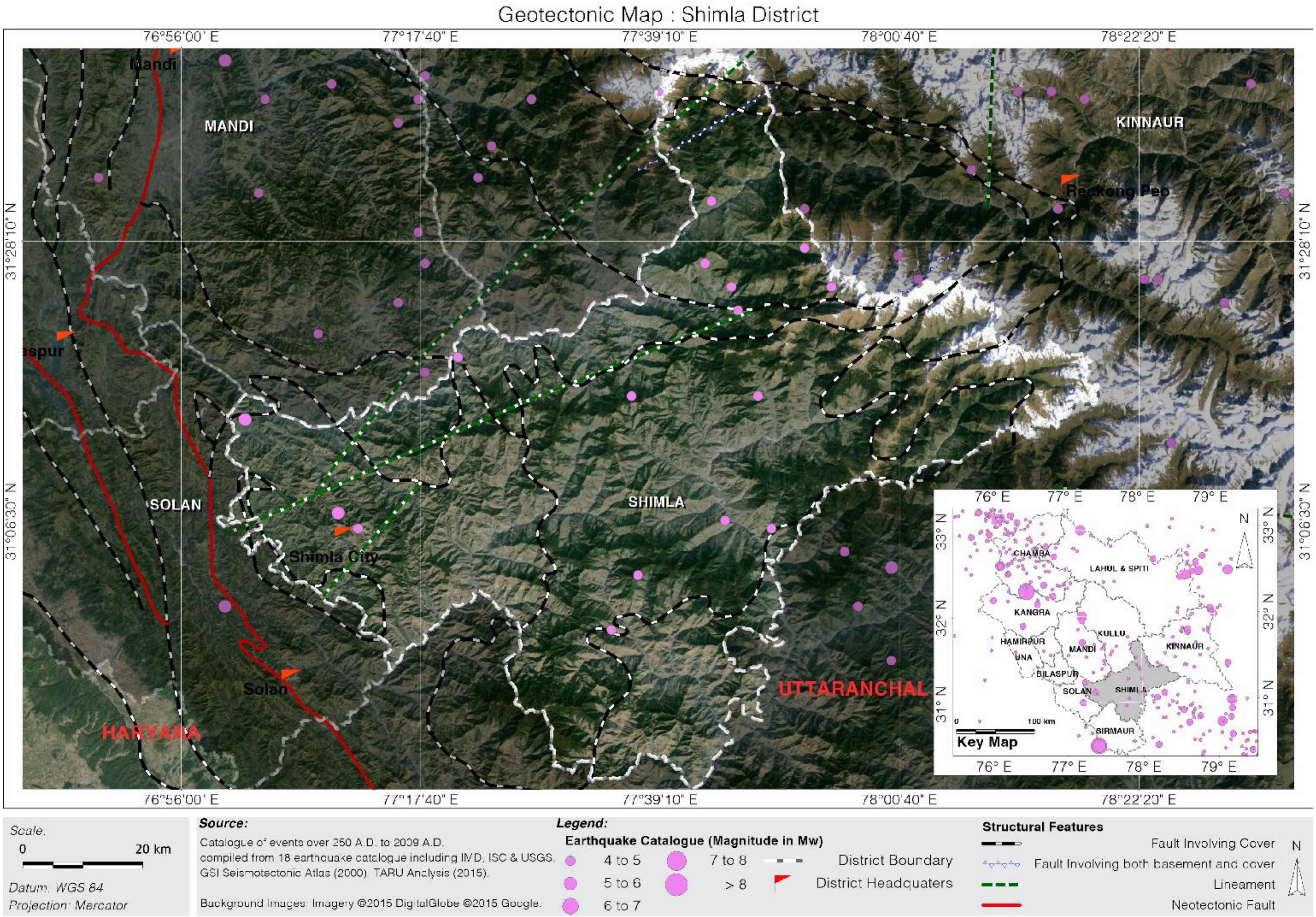
The Indo-Gangetic plain also known as Himalayan foredeep lies in between peninsular shield and the Himalayan region (Map 2). This east-west tectonic basin is characterized by several hidden faults and ridges in the basement of the Ganga basin (Gansser 1974; Valdiya 1976). The Delhi-Haridwar ridge which is demarcated by a pair of faults is the continuation of the Aravali mountain into the Himalaya through Haridwar. Similarly Faizabad ridge and Munger-Saharsa ridge denotes the prolongation of the Bundelkhand and Sapura massifs. All the ridges are bounded by faults and are in tectonic continuation from the Indian shield.

These faults have oblique and transverse alignment across the Himalayan tectonic trend. Gansser (1974) pointed out that Gangetic plain is not a sediment- filled fore-deep and it represents the depressed part of the peninsular shield in which several hidden faults exist. The earthquake activity in the Gangetic plain is broadly associated with strike-slip faulting (Gupta 2006). The Gangetic plain is moderately seismic when compared to the Himalaya (Quittmeyer and Jacob 1979). The faults in the Indo Gangetic plain region exhibit a NE–SW trend and are transverse to the Himalayan chain. The Indo-Gangetic region consists of the vast alluvial plains of the rivers Indus and Ganges. The sagging of land during collision of Indian and Eurasian plate created this geological zone. The Indo-Gangetic region is filled by sediments flowing from both the Himalayas and peninsular shield regions. The thickness of the alluvial deposit is of the order of 1.5-6 km and conceals the solid geology of its basement. The average elevation in this region is about 200 m.

Seismotectonic Map

Seismotectonic maps for HP have been prepared using the Seismo-tectonic Atlas of India (GSI 2000). These drawings are prepared such that all the important seismo-tectonic features within the radius of 500 km around the HP state are captured. For PSHA, it is necessary to delineate the spatial structure of the seismic zones and the faults within these zones that can be associated with past epicenters. The fault map and seismicity map shows that there are some regions that are more active than others. This activity is correlated with the number of occurrence of past earthquakes and also with the presence of faults and lineaments.

Map 2 shows the geologic setting and the past epicentres in the surroundings of Shimla, which can effect the city in future. There is a possibility that not all past epicenters can be uniquely identified with particular faults. This gives rise to the postulation of diffuse aerial sources in some places to be the cause of seismic activity. However, for the purpose of the present work, it has been accepted that only line sources will be considered and all known activity will be attributed to mapped faults only.



Map 2: Seismotectonic setting of Shimla district

1.2.3 Multi-Channel Analysis of Surface Wave (MASW) Tests

After determining the earthquake recurrence relation, the next step is to estimate the local site condition within Shimla. It is recognized that the shear wave velocity of the top 30 m of the strata is a good indicator of the elastic soil response (IBC 2003). Hence, in this work, the variation in the shear wave velocity (Vs) is estimated using MASW test.

Site Selection

The following criterions were followed in the process of selecting suitable test sites:

1. Importance
2. The site has to located within city limits (preferably)
3. Near highly important structures such as hospitals, administrative buildings, bridges, heliports, schools, etc. as they are highly imporpotanct during an emergency and are meant to withstand maximum credible earthquake (MCE) seismic events.
4. Size
5. The site has to be an open ground of minimum 20m x 20m
6. Noise free: Traffic Noise - test sites should be preferably located away from road/rail/air/pedestrian traffic, road works, heavy machinery, etc.

Based on the above criteria, the MASW tests were conducted in 13 sites in Shimla. In addition the borehole data from Central Ground Water Board was also used for understanding the soil characteristics in two locations.

Experimental Setup : The instruments used for this MASW survey consists of the following components:

1. Geode ultra-light exploration seismograph, 24-channel, from Geometrics. Properties: 24 bit, ultra-high resolution 20 kHz bandwidth (8 to 0.02 ms sampling), low distortion (0.0005%), low noise (0.2 μV), stacking accuracy (1/32 of sample interval)
2. Geophones (Figure 24), 5-24 nos. of 4.5 Hz frequency
3. Active source: sledge hammer (8 kg), strike plate
4. Battery: 12 V

1.2.4 Seismic Refraction Survey

Seismic refraction survey is a geophysical technique widely used to characterize the underlying soil strata. In this study, a controlled active source generates the seismic waves and are recorded by an array of equally spaced geophones. These geophones record the travel time of the seismic waves and show the refractions waves caused due to the differences in the characteristic property of different underlying soil layers. The active source is a sledge hammer of weight 8 kg. Image 3 shows a schematic view of the seismic refraction survey carried out at the test sites. The source is always placed at a known offset from the array of receivers.

There are five different locations at which the source is placed while carrying out the MASW tests at each of the test location with an offset distance same as that of the geophone spacing. These positions are along the line with an offset from the first and the last geophone and perpendicular to the line at an offset from the first, middle and last geophone. The receivers or the geophones are placed in equally spaced linear array and can detect the vertical component of the ground motion caused due to the source. The data from all the geophones are collected by a geode and are sent as digital records to a connected computer.

The MASW tests were performed at 13 sites spread across Shimla and its analysis has been shown in Tables 5 and 6. The altitudes of these test sites range from 1760 m to 2074m. The measured Vs30 values range from 254 to 779 m/s and hence the site-4 with the Vs30 value of 779 m/s (> 760 m/s) is a type B site, sites 1,5,8,9,13 &14 fall under class C while the rest of the 6 sites are type D sites.

Sr No	Site ID	Location				Average Vs30	Soil Type
1	Shimla1	31.10°	N	77.15°	E	525	C
2	Shimla2	31.10°	N	77.11°	E	254	D
3	Shimla3	31.09°	N	77.14°	E	351	D
4	Shimla4	31.09°	N	77.14°	E	779	B
5	Shimla5	31.09°	N	77.15°	E	367	C
6	Shimla6	31.11°	N	77.16°	E	346	D
7	Shimla7	31.12°	N	77.18°	E	352	D
8	Shimla8	31.08°	N	77.17°	E	378	C
9	Shimla9	31.10°	N	77.17°	E	472	C
10	Shimla10	31.08°	N	77.17°	E	296	D
11	Shimla11	31.08°	N	77.18°	E	329	D
12	Shimla13	31.09°	N	77.21°	E	541	C
13	Shimla14	31.12°	N	77.22°	E	494	C

Table 1: Site wise soil type and Vs30 values

Site class	Soil profile name	Soil shear wave velocity s (m/s)
A	Hard rock	s > 1500
B	Rock	s < 1500
C	Very dense soil and soft rock	360 < s < 760
D	Stiff soil profile	s < 360
E	Soft soil profile	s < 180

Table 2: Soil classification based on Vs30

Image 2:
Array of Geophones

Image 3:
V 30 Data Collection

1.2.5 Ground Motion Relations

After determining the earthquake recurrence relation and local site condition, ground motion relation valid for the region under consideration has to be derived (Map 3). Attenuation equation is a key component in PSHA. This equation describes the average or other moments of the random hazard parameter in terms of magnitude and distance. The instrumental database for Himalayan and Indo-Gangetic region is sparse and cannot be used to derive attenuation relationships.

Hence, attenuation equations in such regions have to be based on simulated ground motions, instead of a few past recordings. Stochastic seismological model originally proposed by Boore (1983) is a viable alternative and is used worldwide for deriving attenuation relationships in regions lacking strong motion data.

1.2.6 Probabilistic Seismic Hazard Analysis

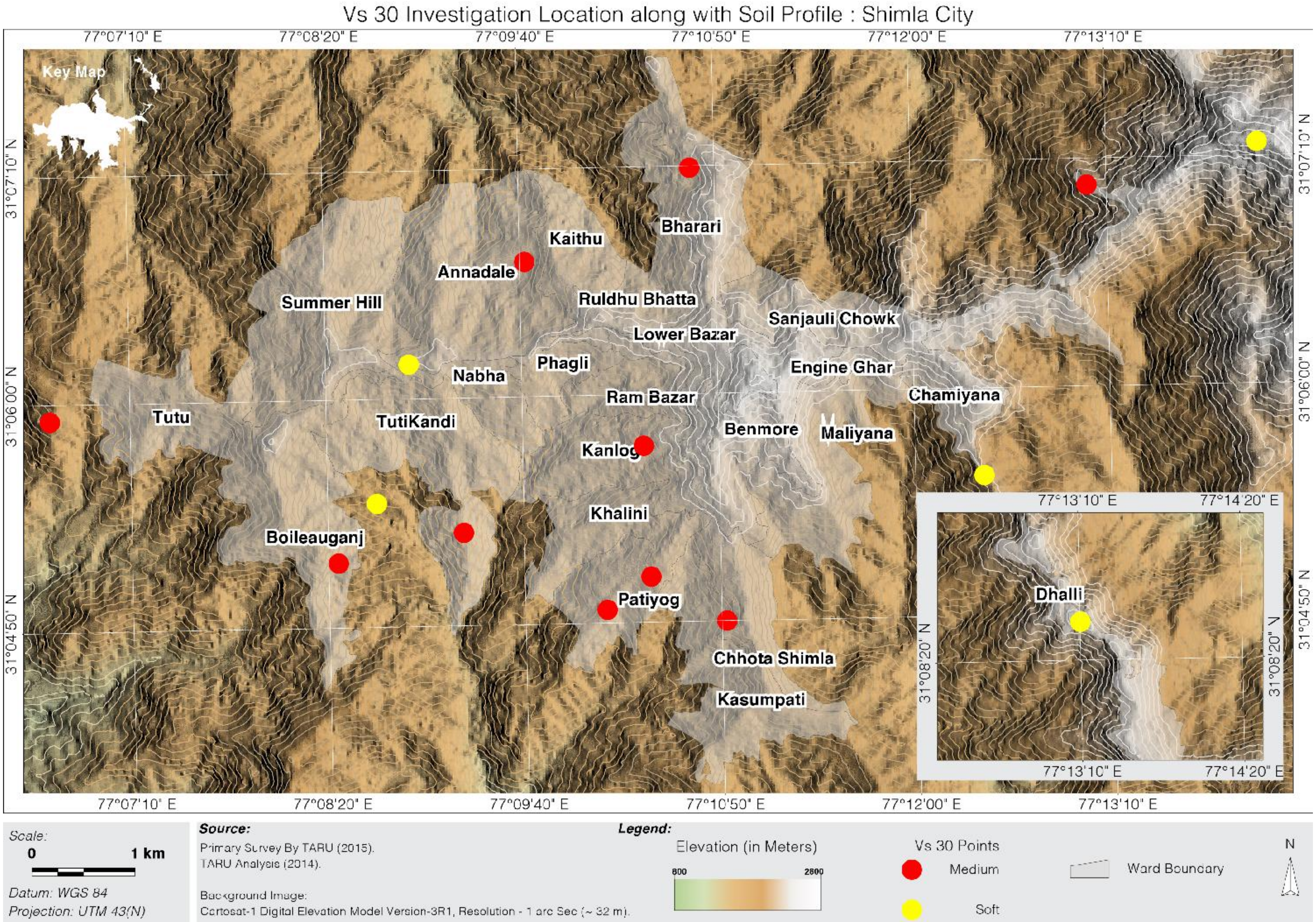
Hazard maps for peak ground acceleration (PGA) and spectral acceleration have been derived for HP by performing detailed PSHA. A circular region of radius 500 km around the target sites was taken and more than 195 faults have been considered in estimating the future seismic hazard. The seismic hazard for the region is mainly controlled by the MCT and MBT faults in the Himalayan region. The recurrence relation for the seismic zones was found from the maximum likelihood method of Kijko and Sellevoll (1989) including incompleteness and uncertainty of the database. New ground motion relations including local soil conditions are derived for Himalayan and Indo-Gangetic regions. Detailed seismic hazard curves have been computed considering all the uncertainties.

From these seismic hazard curves response spectra corresponding to 25-year, 50-year, 100-year, 200-year, 475-year, and 2475-year return periods have been found. Uniform hazard response spectra (UHRS) for twelve important cities have been obtained from PSHA. The obtained results can be further used for seismic design for new structures in HP. The obtained hazard curves combined with UHRS can be used to construct risk maps for HP.

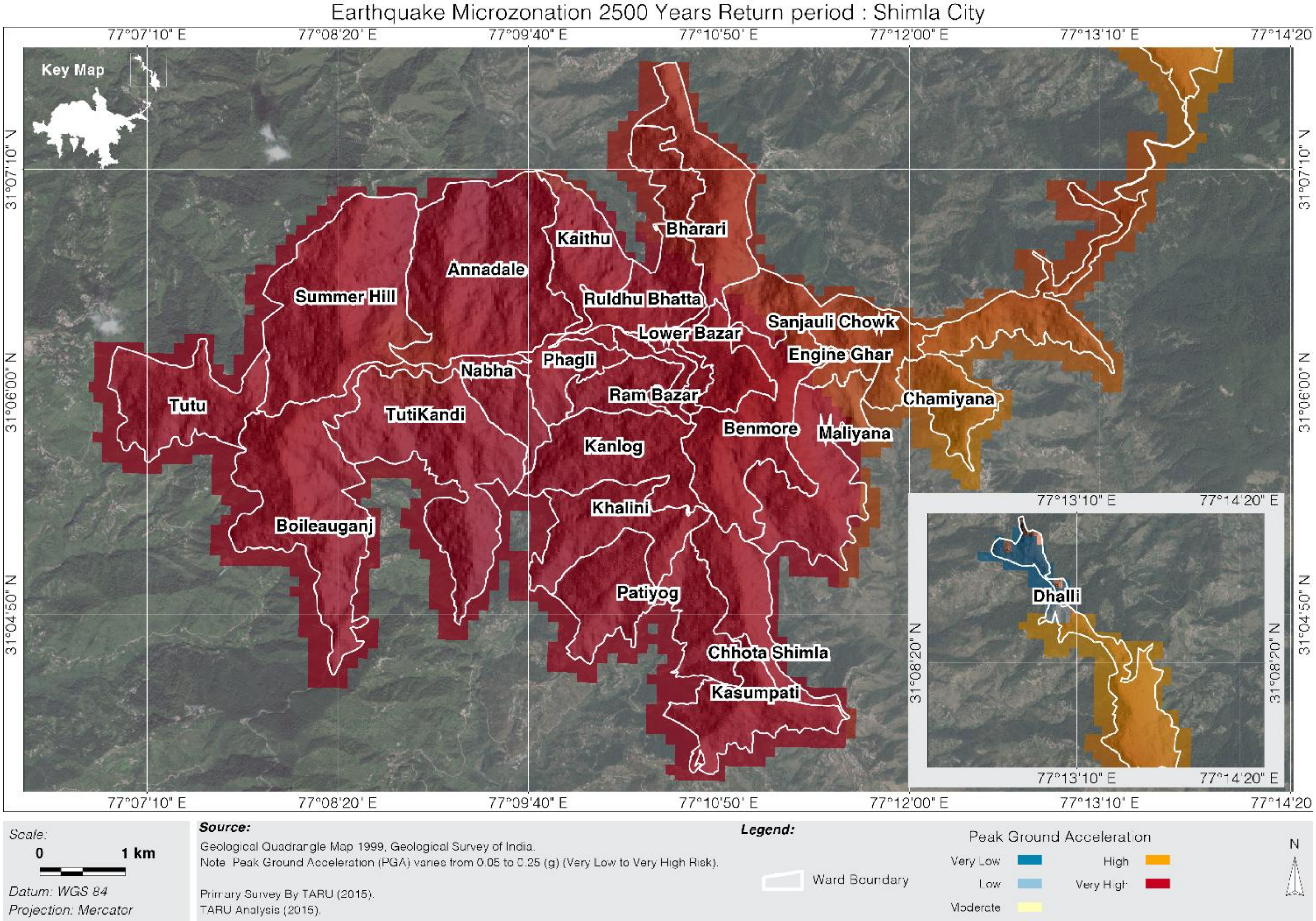
Figure 30 immediately provides a synoptic view of the spatial pattern of the seismicity in the controlling region. As per the available data, Himalayan and Indo-Gangetic seismic belt influences maximally the seismic hazard in Shimla.

1.2.7 Microzonation

The effect of the PGA on the city of Shimla was further analysed by characterising the soil profile across the city. A surface zonation profile of Shimla was created using the local geology as characterized by GSI in 1: 50,000 map and also by using information from the V30 profile. Weightages were given to surface characteristics in the range of 1 to 3 depending upon their hardness ratio. Since V30 profiles were derived using the MSAW method, the hardness obtained through this method were weighted more in comparison to the geology map in the ratio of 3:1. The resultant earthquake hazard profile is presented in Map 4.



Map 3: Vs30 Investigation locations



Map 4: Seismic microzonation for a 2500 year return period (PGA)

1.3 Landslide Hazard Analysis

1.3.1 Methodology

For estimation of the landslide hazard of Shimla, the Bureau of Indian Standards (BIS) guidelines of 1998 (BIS 14496 Part 2), a standard reference document among the disaster management practioners has been used. This guideline uses six geo-environmental parameters called landslide hazard evaluation factor (LHEF) like lithology, structure, slope morphometry, relative relief, land use, land cover and hydrological condition which are assigned ratings as per the range described in the BIS guideline. The values are determined for each facet in the study area. The facets are parts of hill slopes having uniform direction and inclination and are enclosed by natural geomorphological elements like ridges, streams, rivers, break in slope etc.

The calculated LHEF values are used as summed up floats for determining the total estimated hazard (TEHD) which provides the information for dividing the area into various hazard classes. The data products used for the study are of two types- hard copy maps, atlas, and digital data like ASTER. Data has been captured, synthesised and analysed. The results obtained have been validated with field observations and the results show very good correlation with the field observations.

1.3.2 LHEF parameters

Lithology

The Shimla city is situated in the foothills of the Himalayas. While the central part of the city is thickly urbanised and not easy to find rock exposures at every place, in other parts rock exposures are available. The rocks exposed are mostly schists and phyllites. The rocks are traversed by three sets of joints. The rocks are mostly weathered to a fairly high degree (Image 4), which at many places are forming rock fall zones and scree fall zones. The weathering grade of these rocks vary from W0 (fresh rock) to W3 (highly weathered i.e. 50% to 75% of the rock material is decomposed and / or disintegrated into the soil. There is hardly any slope wash material on the slopes though there are steep slopes in the survey area. At some places the rocks are stained due to leaching which may have been facilitated by the weak planes on the rocks.

Image 4: Weatherd phyllites in Shimla

Structure

Shimla falls between two major tectonic elements of the Himalayas- the Main Central Thrust (MCT) in the north and Main Boundary Thrust (MBT) in the south (reference: Seismotectonic Atlas of India and its environs, GSI 2000). The area has also been witness and been affected to various degrees in response to the earthquakes in the region viz. Kangra 1905 (M 8.0), Chamba 1945 (M 6.5), Dharamshala 1978 (M 5.0), Kathua (M 5.2), Dharamshala 1986 (M 5.5) and Chamba 1995 (M 4.9).

Shimla city is traversed by a ridge which has a general east-west orientation. The ridge also divides two major river basins, Yamuna to the south and Sutlej to the north. There are three sets of joints in the rocks of the area. One set of joints is bedding parallel and has a general trend of N280°-330°and are dipping moderately to steeply (24°-57°) (Image 4).

Other set of joints, also striking generally in the same direction as the bedding joints but these are dipping very steeply and at places are sub-vertical.In many places a third set of joints can be observed that is striking dominantly south-westerly (185°-225°) and also dipping steeply to sub vertical. Due to the presence of these three sets of intersecting joints the rocks form wedges (Image 5). The wedges are small scale (~2X2X2 cms) to (~0.5X0.5X0.5m, more in some places) depending upon the closeness of spacing of joints. Places where the joints are closely spaced, small heaps of scree fall zones are formed at the base of road cuts/ cliffs (Image 6). Wider spacing of intersecting joint sets are causing formation of overhangs at many places which are introducing element of impending disaster (Image 7).

Image 5: Interesting set of joints in Shimla area.

Slope Morphometry

Slope morphometry has been used in the study to categorize the area on the angle of inclination of the slopes which is a major contributing factor for stability of the slopes. Data from 1:50,000 toposheets and satellite images have been used for identification of slopes in the area and these have been later classified into the five tier classification following BIS 14496 (Part 2): 1998.

Image 6: Scree heaps at the base of cliff section, formed due to intersection of closely spaced joint sets.

Image 7: Wider spaced intersecting joints forming overhangs that are falling on roads.

The area falls under two class of slopes, gentle slope (16°-25°) and moderately steep slope (26°-35°). Landslide incidences and rock fall signatures are distributed in these slope classes more where there is anthropogenic intervention in the form of widening of roads, cutting of the base of the slopes for construction activities, modification of slopes etc. The areas falling under gentle slope are Gaiety Theatre, High Court, Municipal Corporation, Himruja and south-western part of Shimla city. On the other hand, areas falling under moderately steep slope class are RTO, north of IGMC, Church, Secretariat, Jakhoo temple and St. Bede's College.

Relative Relief

Relative relief represents the maximum height of a facet, from bottom (valley floor) to top (ridge / spur) in the direction of slope inclination. In Shimla city the entire area is falling under high relative relief class which is more than 300m.

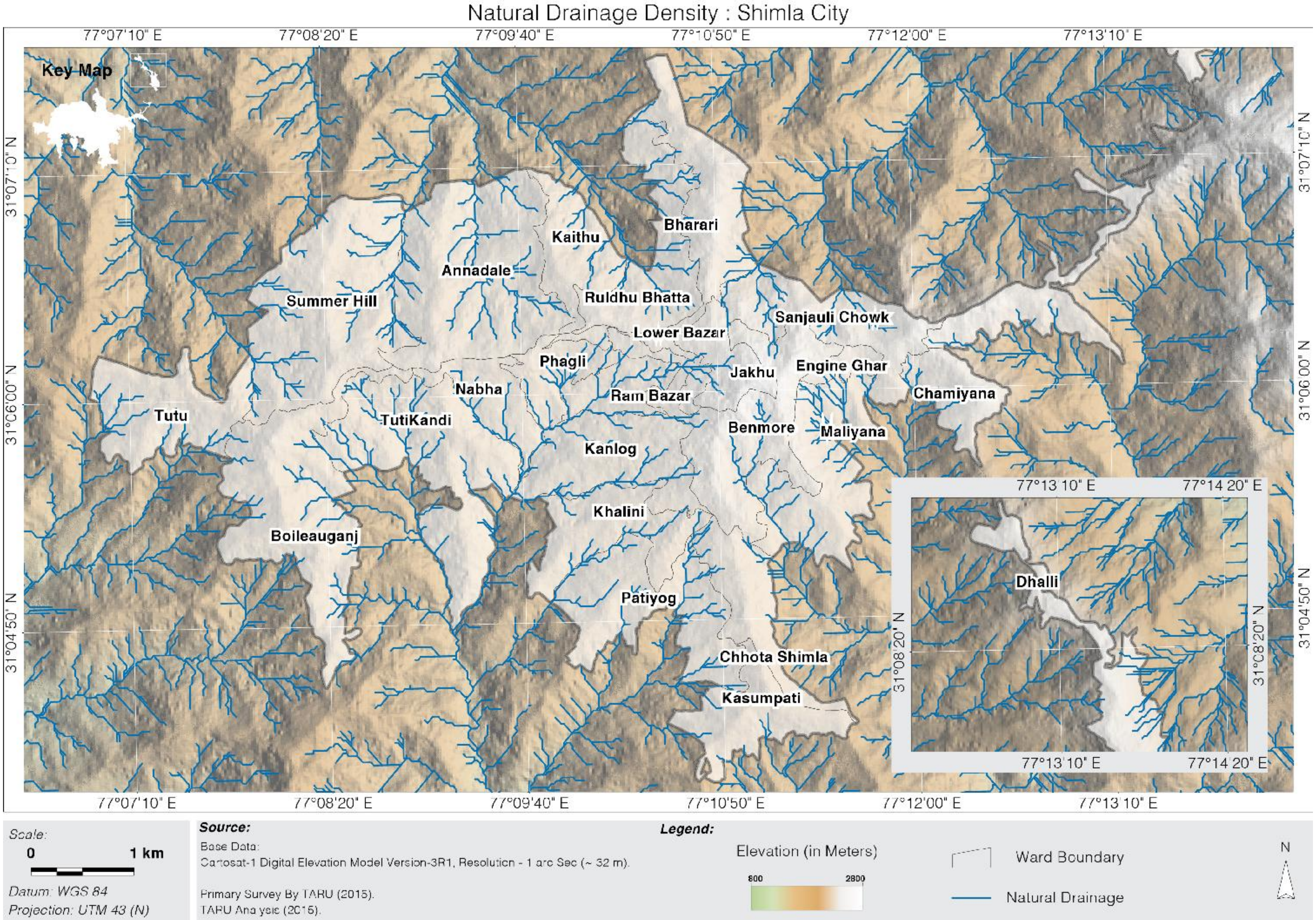
Drainage

The drainage map (Map 5) was prepared from the traced out drainage by measuring the total length of lineaments in square kilometers. The drainage density map is classified in to five categories based on the range of values - very high density, high density, moderate density, low density, very low density.

Land Use/ Land Cover

Land Use/Land Cover (LULC) is an important parameter of landslide hazard classification as slope instability in many cases is directed by the practice of using available land in the area. Human interference and developmental practices can destroy forest cover, modify the natural slope angles, lading the top of critical slopes or cut the toe parts of such slopes. These are all facilitators of slope movement and the inputs derived from LULC pattern is of high importance. The land use practices and the classification of the land in the area falls under two categories- thickly vegetated forest area as observed around Jakhoo temple and, moderately vegetated area. ~54% of the area constitutes moderately vegetated while ~ 46% of the area is under thick forest cover.

The first category is under very dynamic process of developmental practices (Image 8) and resulting interventions, while the thickly forested parts are also showing signatures of slow creep manifest by many signatures like bending of tree trunks in the area (Image 9).



Map 5: Shimla - Drainage Density

Image 8: Filling of cut slopes for developmental purpose.

Image 9: Bending of tree trunks in stressed slopes in thickly vegetated parts

Image 10: Poorly intercepted slope water flowing on roads. signatures of initiation / formation of pot holes.

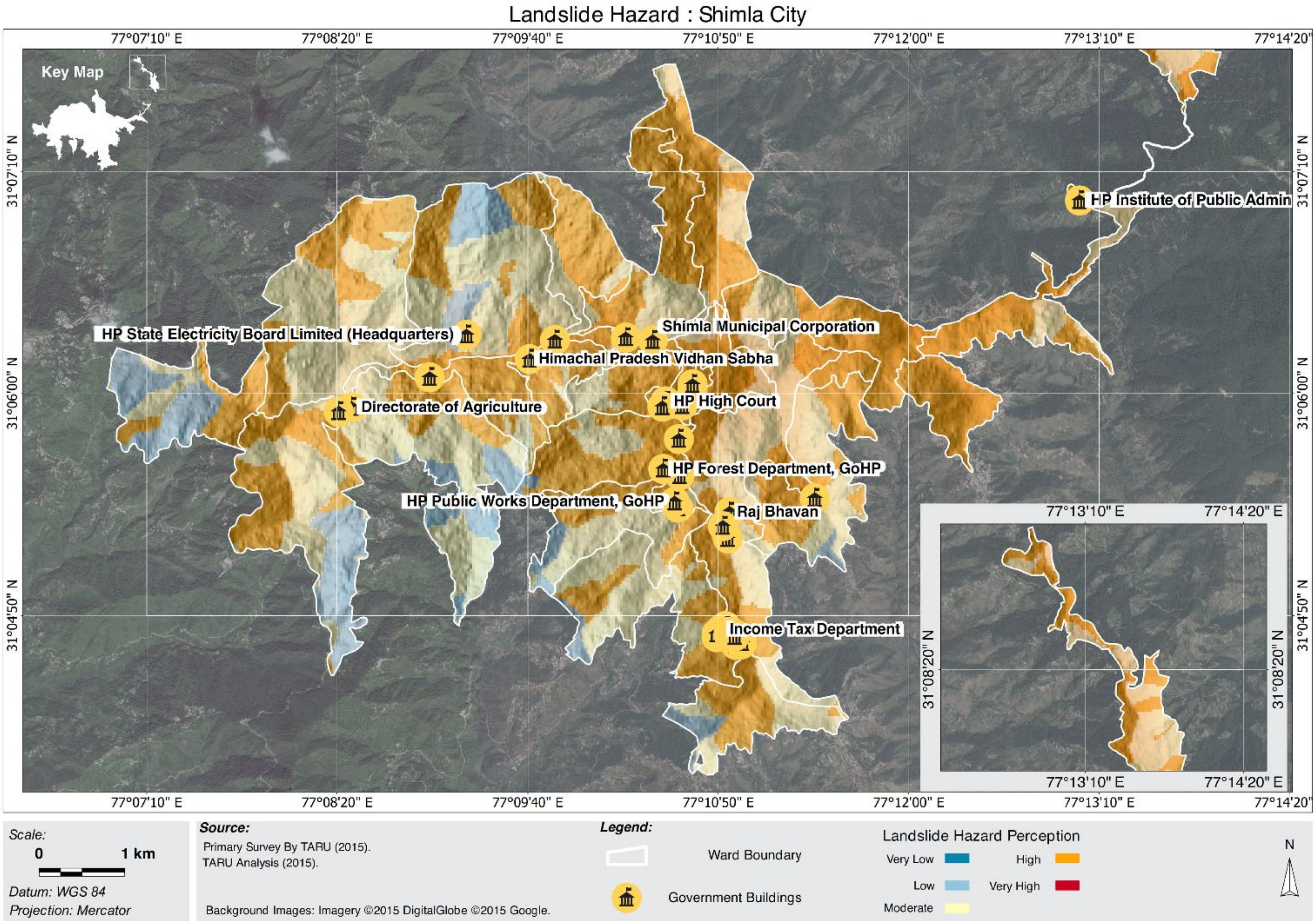
Image 11: Wet roads over a longer period of time showing distress signatures of initiation / formation of pot holes.

Hydrological Condition

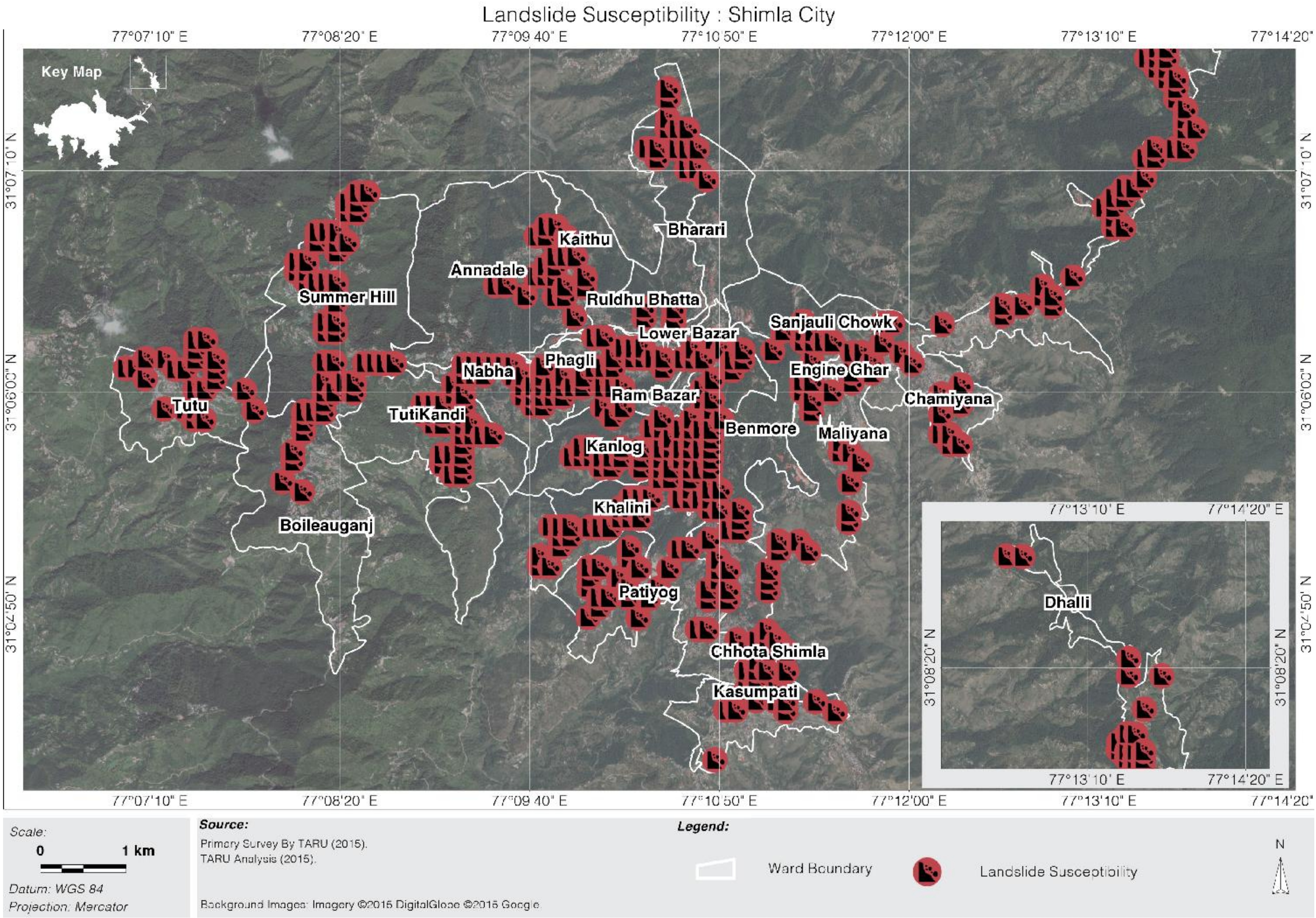
Hydrological condition is important factor of landslide hazard analysis as water acts as lubricator and ultimate facilitator for movement of slopes. The hydrological condition in the area has been recorded through field observations in the exposed rock surfaces, slopes. Accordingly, the values of hydrological condition have been assigned to the appropriate facets. According to the field observations there are two hydrological classes in the area, dry and damp (BIS 14496 Part 2):1998. Nearly 44% of the area is observed to be under dry category while ~ 56% of the area shows signatures of dampness. It is important mention here that the dryness or dampness in many areas are not solely governed by the natural conditions and are many times induced by improper drainage of water from the slopes. In many parts the engineering solutions provided earlier like interceptor drains are poorly maintained and in some instances have been tampered with. This has caused accumulation of water on slopes and road surfaces resulting in corrosion of roads, and conditions leading to movement of slopes. The process of degeneration of slopes and surfaces are progressing in the area in two stages- in the first stage the unchannelised water from slopes flows over plain surfaces like roads for a long period of time (Image 10) and in the second stage these corrode and damage the surfaces and erode the slopes (Image 11).

1.3.3 Landslide Hazard of Shimla City

After assigning corresponding LHEF values for the six landslide parameters (lithology, structure, slope morphometry, relative relief, LULC and hydrological conditions) as per BIS 14496 Part 2:1998, the assigned values have been summed up for calculation of the total estimated hazard (TEHD) for the area for undertaking the study. The TEHD values for the area fall under three categories- low hazard zone (TEHD value between 3.5 and 5.0), moderate hazard zone (TEHD value between 5.1 and 6.0) and, high hazard zone (TEHD value between 6.1 and 7.5). 43 facets (16% of the area) of the area fall under low hazard, 141 facets (51% of the area) fall under moderate hazard and 92 facets (33% of the area) are under high hazard category (Map 6). Apparently, the hazard scenario of the area is fairly high. It is to be mentioned here that being placed under even the low and moderate hazard conditions does not allow much scope for complacency in a place like Shimla as in present times when anthropogenic interference is a major contributing factor in causing instability of the slopes. This also adds to the fact that modification of the present geo-environmental parameters like land use practices, slope modification, unchannelised slope water are likely to increase the susceptibility of the area which is undergoing a lot of change in land use pattern.



Map 6: Landslide Hazard map of Shimla



Map 7: Landslide hazard susceptibility in Shimla city

1.4 Urban Heat Island

1.4.1 Introduction

Anthropogenic change, associated with land cover, appears to be tightly coupled with urban heat. The type and nature of the human landscape around a city, to satisfy various social and economic needs, has given rise to several phenomena, such as air pollution, water pollution and micro-climate change (Kondratyev and Varotsos 1995, Varotsos et al. 2005). It is often observed that air temperature in densely urbanised areas are higher than those of the surrounding areas. Among these urban- rural differences, the most notable and well documented is the phenomenon known as the "Urban Heat Island" (UHI) (Kim and Baik, 2005). Urban heat island of Shimla city is analysed with the help of land surface temperature derived from satellite data and thermal images with Fluke Thermal Imager across Shimla city. The relationship between remote sensing measurements of land surface temperature and biophysical/socioeconomic data has been arrived by utilizing the association rule mining technique. The surfaces associated with urban uses typically radiate more heat as compared to its rural counterparts. There is a need to quantitatively analyse this contrast in temperature and the biophysical and social characteristics which influence it. Furthermore, in order to consider the urban heat island (UHI) effect, a parameterization is required to account for the urban surface characteristics impacts on the magnitude of land surface temperature (LST) (Rajasekar et al. 2009).

1.4.1 Introduction

Data used - For the analysis of land surface temperature satellite data of LANDSAT 8, thermal band sensor Operational Land Imager (OLI) with resolution of 100 m (Resample 30 m) was used. The date of acquisition was 23 March 2015. Bands considered for analysis are Band 3 (Green) 0.53 - 0.59µm, Band 4 (Red) 0.64 - 0.67 µm, Band 5 (Near Infrared) 0.85 - 0.88 µm and Band 10 (Thermal Infrared OLI) 10.60 - 11.19 µm.

Methodology - There are two steps which are involved in the computation of LST. First was the conversion of sensor derived spectral radiance to the at-sensor brightness temperature (i.e., considering that the emitting source is a perfect black body). Since the emitting source is never a perfect black body, the second step was the correction for spectral emissivity taking into consideration the land use/ landcover types (Rajasekar et al. 2009). Thermal band data is used to convert from spectral radiance to brightness temperature using the thermal constants provided in the metadata file. The formula is as follows:

$T = K2 / \ln(K1/L\lambda + 1)$

Where:

T= at satellite brightness temperature (K)

Lλ =TOA Spectral Radiance (watts/ (m2 * srad * µm))

K1= Band Specific thermal conversion constant from the metadata *(K1_CONSTANT_BAND_x where x is the band number 10)*

K2= Band Specific thermal conversion constant from the metadata *(K2_CONSTANT_BAND_x where x is the band number 10)*

(http://web.cecs.pdx.edu/~derekt/Classes/ME%20411%20Winter%202015/Laboratory/ME411_RemoteSensingLab4.pdf).

Land Use Land Cover Classification

To analyse land surface temperature, land use land cover (LULC) data was developed from the LANDSAT8 2015 image using a semi-automatic technique. An unsupervised classification method (cluster analysis) was chosen to classify the LANDSAT data. ILWIS 3.3 software is used for the cluster analysis. The LULC map consist of five classes. Spectral Emissivity Class assigned to LULC type are-

LULC Class	Emissivity
Dense Forest, Forest	0.987
Grass	0.972
Mixed	0.973
Built up	0.966
Barren Land	0.977

Table 3: Spectral Emissivity Class

Therefore, the land surface temperature can be calculated as:

LST=Tb/[1+(λ*Tb/p) ln(e)]

Where:
Tb= Brightness Temperature in degree kelvin (K)
e = Spectral emissivity
λ= wavelength of emitted radiance
p= h* (c/s) (1.438*10^-2mK)
h= Planck's constant (6.626*10^-34 Js)
s = Boltzmann constant (1.38*10^-23 J/K)
c= velocity of light (2.998* 10 ^8 m/s)

Spatial distribution of land surface temperature is described in Map 8.

In the land surface temperature analysis it is observed that ward Lower Bazar, Ram Bazar, Dhali, Chamiyana, Engine Ghar are the hot spots. In Lower Bazar and Engine Ghar the whole area is densely populated and there are very few trees due to which the temperature of that ward is higher comparison to other wards. Chamiyana and lower Dhali ward consist of barren land which results in increase in temperature.

Image 12: A view of densly populated Lower Bazaar

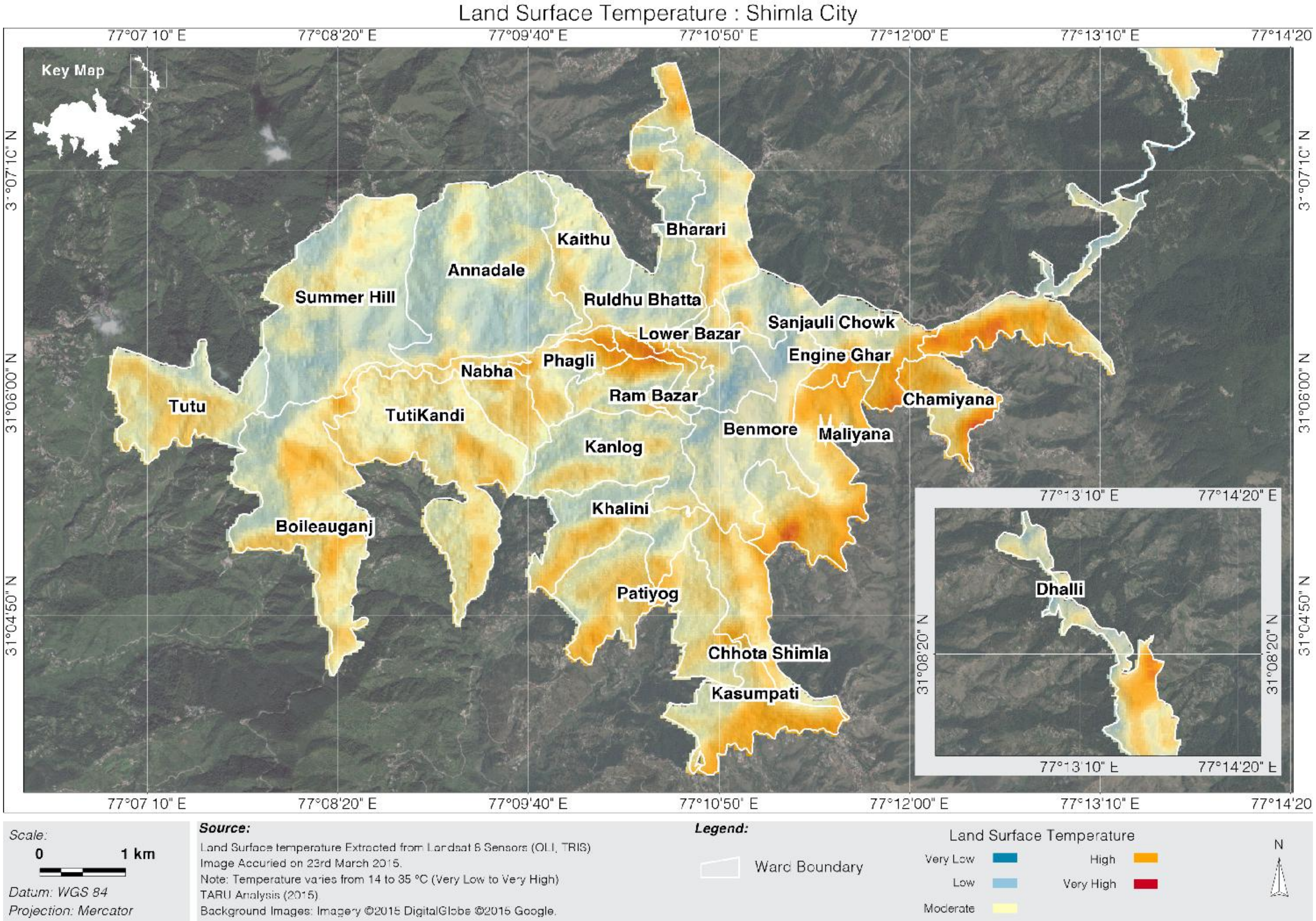
1.4.3 Snow and Hail Storm Hazard

There are many areas in Shimla which experience medium to heavy snow fall. It has been observed that about 11% of all the households that were questioned indicated that they didn't experience a snow deposit. Table 4 explains the deposit of snow (in feet) during an average season.

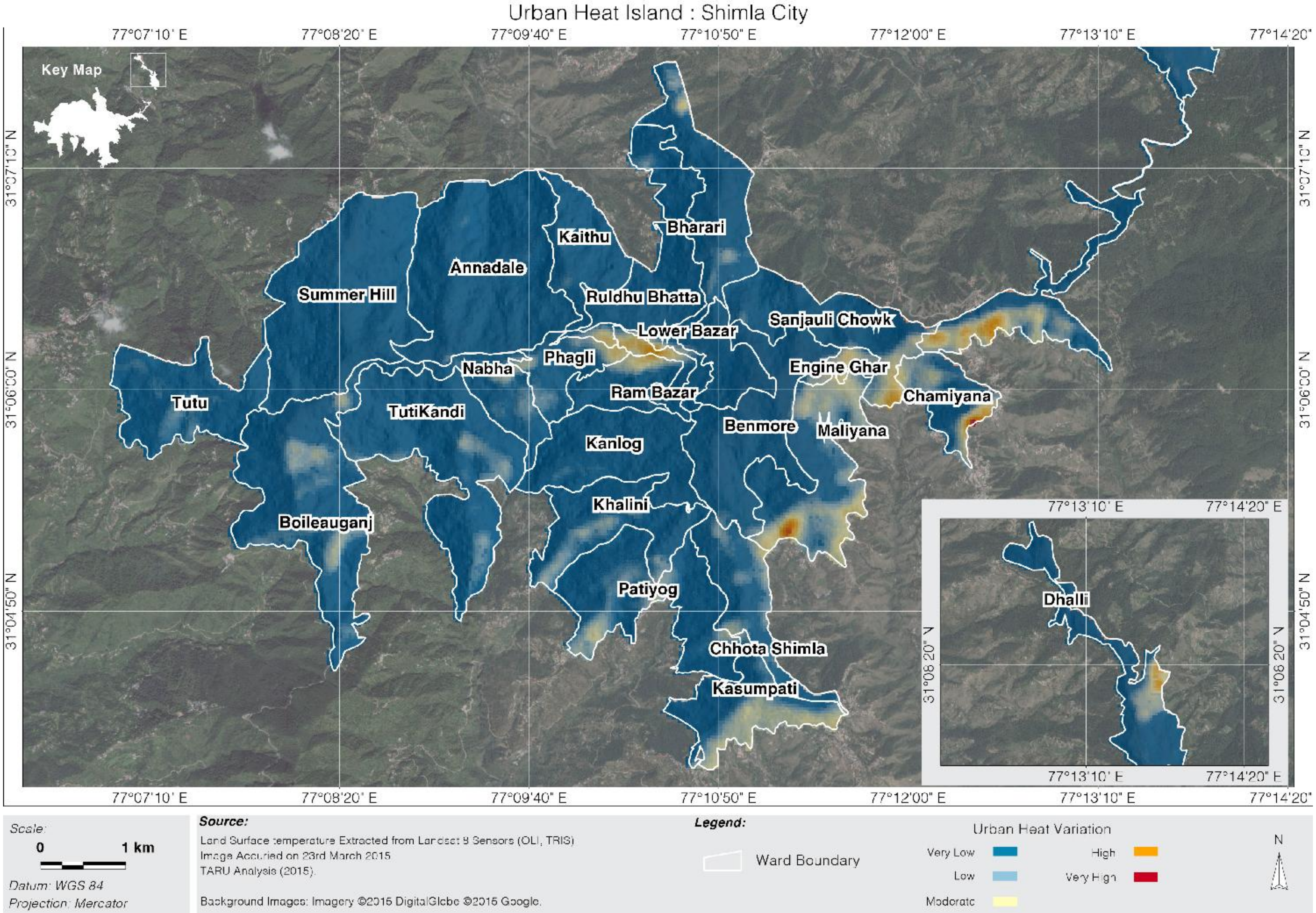
Depth of Snow in feet	No. of households reported	Per cent
0	220	11.2
1	1,021	52.0
2	598	30.5
3	82	4.2
4	32	1.6
5	9	0.5
Total	**1962**	**100**

Table 4: Deposit of snow during an average season

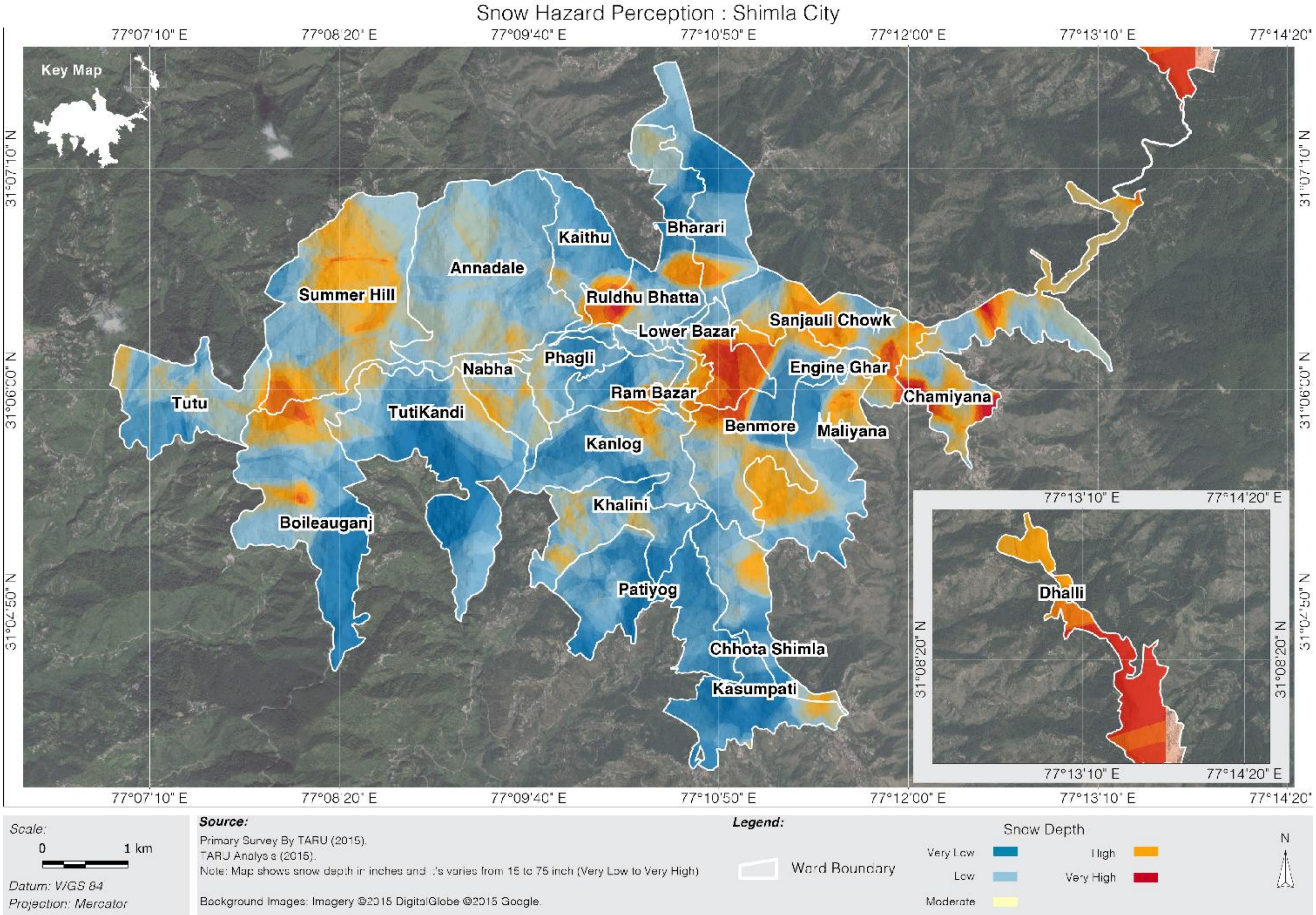
Map 10 shows the areas that have reported more depth of snow accumulation. A reason for predicting snowfall is that during intense snows, the heaviest snowfall can occur in surprisingly narrow time scale, and on a smaller scale than what observation networks and forecast zones can see. Also, the extremely small temperature differences that define the boundary line between rain and snow make the task of preparedness difficult. Shimla already experiences various forms of snowfall – snow flurry, freezing rain, ice storm and blizzard. The intensity of these events may cause disruption to normal life and the tourist activity may also be hampered. From the Map 10 we can see that the higher reaches within the city are the ones that experience higher snowfall. However, the melting of snow and drainage of the same becomes a problem with the natural drainage networks getting choked or disturbed with current building construction activity.Many of the surveyed households have complained about the hail storm that cause disruption to normal day to day activities, as well as financial loss to crops and other economic activities. Map 11 shows the intensity of the hailstorm felt by people across the city. While we may not predict why certain areas experienced more intense hail storm while other areas less, we can prepare the housing stock to withstand the intensity of the hail storm, which are often accompanied by strong winds. The southern slopes of the city experiences more hail storms than the northern slopes.



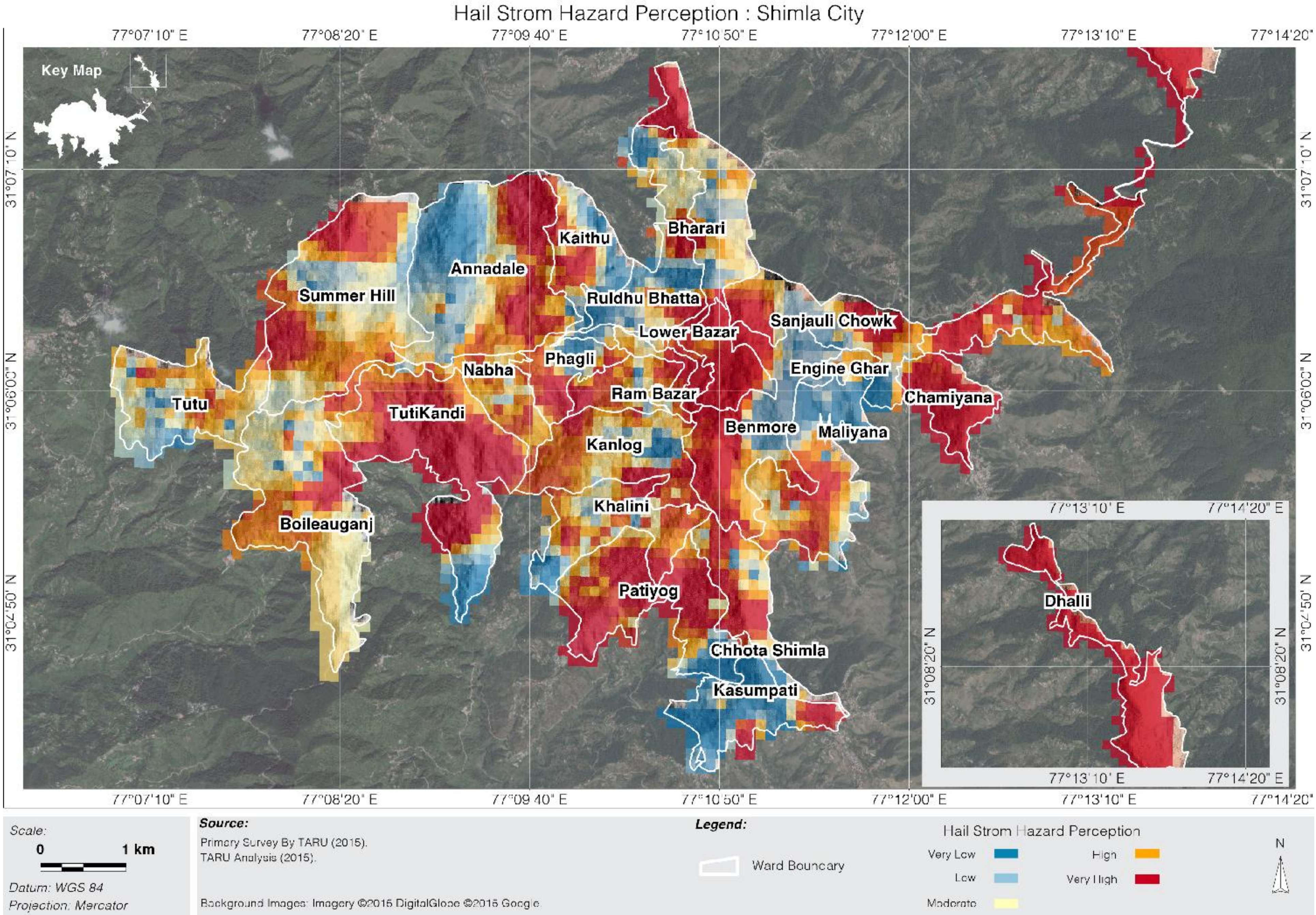
Map 8: Land Surface Temperature of Shimla CIty



Map 9: Urban Heat Island



Map 10: Snow Hazard Perception



Map 11: Hail Storm Hazard Perception

1.5 Fires

Fires in Shimla occur in two different ways – urban fires that originate from anthropogenic activities and forest fires, which originate from anthropogenic activities as well as natural causes like lightening over a mature patch of forest. One of the common reason for domestic fire is the mishandling of cooking fuel and live fire. Table 4 shows the number of households that mentioned about these fires in their vicinity.

1.5.1. Urban fires

There have been many incidents of fire in the city of Shimla. One main reason for these fires to spread and cause huge damages is the nearness of the houses or shops. Many a times, these fires were observed in the densly packed shopping area in Lower Bazar (January 9, 2016 at 3.00am). Some of the well known fire accidents within Shimla city are: Lower Bazar fire of 9 January, 2016; AG Building (Gorton Castle, January 28, 2014); Deepak project fire (Minto Court near Indian Institute of Advance Studies, November 2, 2014). While the losses in these accidents run into crores of rupees, the heritage and architectural loss is irreplaceable.

From the primary survey, 28% of the households have experienced some form of fire accidents, but many of them did not face any losses. The survey respondents have memory of 12 incidents at the neighbour level which caused losses within the city – right from 1947 to 2015. Out of the sampled households, there are 16 houses which are having exposed fire in the kitches, while rest of the households use non exposed fires, like induction, microwave and other kitchen utilities. The vulnerability of the housholds in terms of fire is still high, from the point of view of access to fire services. The topic is explained in section.

On an average, about 4% of the households are using open fires for cooking their meals. This may lead to fire hazard.

	Kerosene, Coal, Wood, Dung	LPG
Ward No 1	1	51
Ward No 2	0	81
Ward No 3	3	60
Ward No 4	1	50
Ward No 5	2	94
Ward No 6	18	116
Ward No 7	0	126
Ward No 8	3	32
Ward No 9	3	47
Ward No 10	1	47
Ward No 11	2	45
Ward No 12	0	17
Ward No 13	0	20
Ward No 14	1	36
Ward No 15	0	15
Ward No 16	0	46
Ward No 17	3	65
Ward No 18	14	83
Ward No 19	3	162
Ward No 20	3	104
Ward No 21	6	147
Ward No 22	3	77
Ward No 23	5	179
Ward No 24	1	116
Ward No 25	4	90

Table 5: Wardwise fuel used

1.5.2. Forest Fire Hazard Analysis

Forests are a major natural resource, which play crucial role in maintaining environmental balance. The health of forest in any given area is a true indicator of the ecological condition prevailing in that area. Frequent occurrence of forest fires may lead to depletion or extinction of some of the valuable plant and animal species. Even human beings are adversely affected either directly or indirectly. Thus forest fires can be considered to be a potential hazard with physical, biological, ecological and environmental consequences which results in partial or complete degradation of vegetation cover thus modifying the radiation balance by increasing the surface albedo, water runoff and raising the soil erosion (Darmawan and Mulyanto, 2001). Fuel is any material capable of burning. In forests, fuel is the vegetation, branches, needles, standing dead trees, leaves, and man-made flammable structures (Anon, 1999). Technically, fire is defined as the rapid combustion of fuel, heat and oxygen. All these three elements in some proportion start and spread fire. It is a chemical reaction of any substance that will ignite and burn to release a lot of energy in the form of heat and light (Rawat, 2003). To start a fire an external source of heat is required along with oxygen. Heat is measured in terms of temperature.

Land Type	Area (in Sq. Km)	% of Total Area
Forest area (forest record)	37,033	67%
Land put to non-agricultural uses	4,716	8%
Net area sown	5,414	10%
Fallow lands (current & other fallows)	752	1%
Culturable Wastes	1,280	2%
Land under misc. tree crops not included in cultivation	611	1%
Permanent pastures and other grazing lands including alpine pasture, barren & un-culturable lands including alpine pastures, barren & un-culturable waste etc.	5,867	11%
Total Geographical Area	**55,673**	**100**

Source: Himachal Pradesh Forest Department, Government of Himachal Pradesh
Table 6: Land Utilization of Himachal Pradesh

According to National Forest Policy, 1988, at-least two third (i.e. 66%) of the geographical area should be under forest in the hilly states like Himachal Pradesh.

The forests of the Himachal Pradesh can be classified into two major categories including coniferous forests and broad-leaved forests. Distribution of various species follows fairly regular altitudinal stratification. The vegetation varies from dry scrub forests at lower altitudes to alpine pastures at higher altitudes. In between these two extremes, distinct vegetational zones of mixed deciduous forests, bamboo, chil, oak, deodar, kail, fir and spruce, are found.

The richness and diversity of the flora can be gauged from the fact that, out of total 45,000 species found in the country as many as 3,295 species (7.32%) are reported in the State. More than 95% of the species are endemic to Himachal Pradesh and characteristic of western Himalayan flora, while about 5% (150 species) are exotic, introduced over the last 150 years (Himachal Pradesh Forest Department, 2013).

Existing scenario of land utilization in Himachal Pradesh has been described in Table 6. Legal classification of forest in Himachal Pradesh is presented in Table 7.

Forest Type	Area (in Km^2)	Area (%)
Reserved forests	1,896	5.12
Demarcated protected forests	11,387	30.75
Un-demarcated protected forests	21,656	58.48
Unclassified forests	976	2.63
Others (managed by forest department)	370	1.00
Not managed by forest department	748	2.02
Total	**37,033**	**100.0**

Source: Himachal Pradesh Forest Department, Government of Himachal Pradesh
Table 7: Legal Classification of Forest

1.5.3. Forest Fire in Himachal Pradesh

The forests of western Himalayas are more vulnerable to forest fires as compared to those in eastern Himalayas. Frequency and intensity of forest fires has increased since 1990 in Himalayan region. Forest fires are an annual phenomenon in state of Himachal Pradesh. This is a most frequent hazards.

Fire season starts from mid-April, when there is no rain for months, forests become littered with dry senescent leaves and twinges, which could burst into flames or ignited by the slightest spark. In June 2007, forest fire destroyed 2,000 hectares of forest in Himachal Pradesh (SAARC-DM Center, 2007). The district of Shimla has experienced around 29 events of fires in the last decade.

Forest fires are mostly anthropogenic in nature in Himachal Pradesh and may occur due to the following reasons:

- Forest floor are often burnt by villagers to get a good growth of grass in the following season or for a good growth of mushrooms,
- Wild grass or undergrowth is burnt to search for animals,
- Firing by miscreants,
- Attempt to destroy stumps of illicit fallings.

Categories of Forest Fires

The fire can be defined as an uncontained and freely spreading combustion which consumes the natural fuels of a forest i.e. duff, litter, grass, dead branch, wood, snags, logs, stumps, weeds, brush, foliage and to some extent green trees (Brown and Davis, 1959). Basically forest fires have been categorized in to three types:

- **Ground Fires**: Ground fires are not easily predictable as it spreads within the canopies rather than on top of organic matter. It consumes organic matter like duff, musk or peat present beneath the surface litter of the forest floor. It has unique characteristic of having a smoldering edge with no flame and little smoke. Ground fires are most hard to handle and there should be proper policy and practice for control agencies.

- **Surface Fire**: Surface fire is characterized by a fast moving fire, which consumes small vegetation and surface litter along with loose debris.

- **Crown Fire**: Crown fires advances from top to top of trees or shrubs without any close link with surface fire. It is fastest to spread and most destructive for trees and wildlife.

Map 12 shows land-use type and fire incidences in the state of Himachal Pradesh.

Causes of Forest Fires

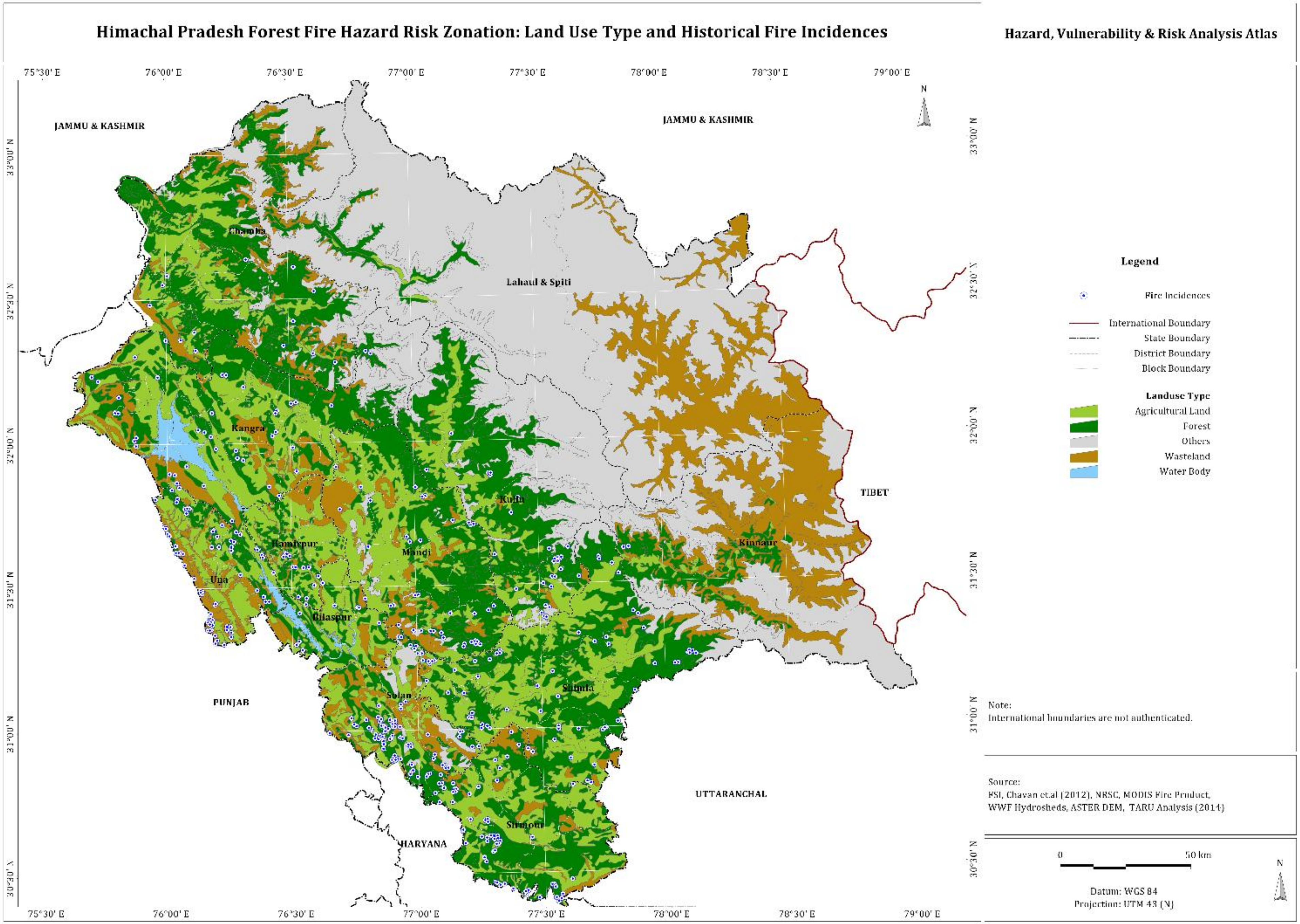
Basically causes of forest fire have been classified into three main categories:

- **Natural:** These are the fires which cannot be averted as these occurs naturally due to lightening, rolling of stones and rubbing of dry bamboos due to strong wind.

- **Intentional/Deliberate:** Mainly intentional fires are created for the better growth of fodder grass. These fires are also been set by villagers to drive away the herbivores animals, which destroy their crops. Sometimes villagers get annoyed with forest department and deliberately set fire without knowing its consequences. Villagers also set fire for collecting forest products like honey, gum, mahua flowers etc. Railway transport also causes forest fires occasionally. There is less control over fires which are caused deliberately by local dwellers.

- **Un-intentional/Accidental**: Unintentional/ accidental fires are the result of carelessness of human beings such as throwing of burning matchstick or cigarette. Other fires, which occur accidentally, are the spread of fire from labour camps, from picnic sites and other recreational areas due to human activities.

These types of fires are controlled by certain parameters like its proximity to settlements and distances from roads. Although it is not easy to account natural or deliberate fires but the areas prone to fires can be detected and mapped.



Map 12: Himachal Pradesh: Land Use Type and Fire Incidences

Source :Global Land Cover 2000; Forest Department, Government of Himachal Pradesh; Forest Survey of India, Dehradun

Parameters responsible for Forests Fire

The factors required for any fire to take place are availability of air, fuel and heat. Forest fire behavior is dependent on its intensity, spread and integrated factors.

These factors are:

- Vegetation Type / Density: Dense and dry vegetation are more susceptible to fire in comparison to moist and sparse one. Moisture content in vegetation delays ignition.
- Climatic Factors: Climate plays the dominant role in ascertaining the fire prone areas, as they are the main determining factor of vegetation of a given region. Thus drier the climate the more prone is the site for fire.
- Physiographic Factors: Physiographic factors include altitude, aspect and topography of a region. These are the factors, which are mainly responsible for variation in climatic conditions. Thus they indirectly affect the vegetation. Aspect plays a major role in the spread of fire - like southern slopes which are more or less directly exposed to rays of the sun are more vulnerable to fire.
- Topography: Topography influence the wind of a particular region like fire travels more rapidly in up slopes.
- Edaphic factors: Soil plays a vital role in the growth, development and anchoring of the vegetation. And vegetation after decay adds to the fertility of the soil. Distance to Roads: Any physical activity by man, animal or vehicle on the road can cause an unwanted fire. Thus proximity to the road plays vital role in chance of fire.
- Vicinity to Settlements: In settlement lots of human activities can cause fire in the vicinity of settlement, which can start a forest fire and cause havoc.

Some of the main causes of forest fire in Himachal Pradesh are as follows:

- Illegal activities including logging.
- Controlled fire to clear residual material along inspection corridors within forest. Setting fire in order to collect non-wood forest products from interior of the forest.
- To grow fresh grass for the next season.
- Lighting oil lamps in places of worship, which are situated within forests, or in its periphey.

Methodology

The scope of this assessment was limited to assessing forest fire risk and in its zonation. Detailed methodology flow chart has been given in Figure 25.

Following spatial data has been acquired from various sources for forest fire hazard risk assessment.

1. State, district & block/taluka boundaries (Survey of India)
2. Settlements locations (Survey of India)
3. Elevation data (Cartosat, ASTER GDEM 30 m)
4. Land use and land cover (LANDSAT)
5. River network and water bodies (Cartosat, Hydrosheds & Google Earth Pro)
6. Historical fire events (MODIS Burned Area, Forest Survey of India)

In this study, Saaty's (2000) Analytical Hierarchy Process (AHP) method was used for risk mapping and zonation. AHP is a multi-criteria decision making (MCDM) method in conjunction to rank and prioritize the causative factors of fire risk in the study area. Spatial multi-criteria decision analysis is a process that combines and transforms geographical data (input) into a resultant (output). The multi-criteria decision making procedure defines a relationship between the input map and the output map. This procedure utilizes the geographical data, the decision maker's preferences, and the manipulation of the data and preference according to the specified decision rules. Multi-criteria analysis has been used for the evaluation of geographical events (Malczewski 1999).

AHP is a decision-aided method which aims at quantifying relative priorities for a given set of alternatives in a ratio scale, based on the judgments of a decision maker as well as the consistency of the comparison of alternatives in the decision making process. This method has been forced to an effective and practical approach that can consider complex and structured decision. The AHP is proposed in this research in order to assign weightages for various parameters influencing the forest fire. The weights have been decided following the analytical approach suggested by Saaty (1990). A spatial process model has been developed for the decision-making.

In this study, AHP was used to organize decision-making criteria. Pairwise comparison matrixes were made between criteria at each level of the hierarchy and possible alternative causes of decision.

Flowchart explaining
the
Fire Risk zonation

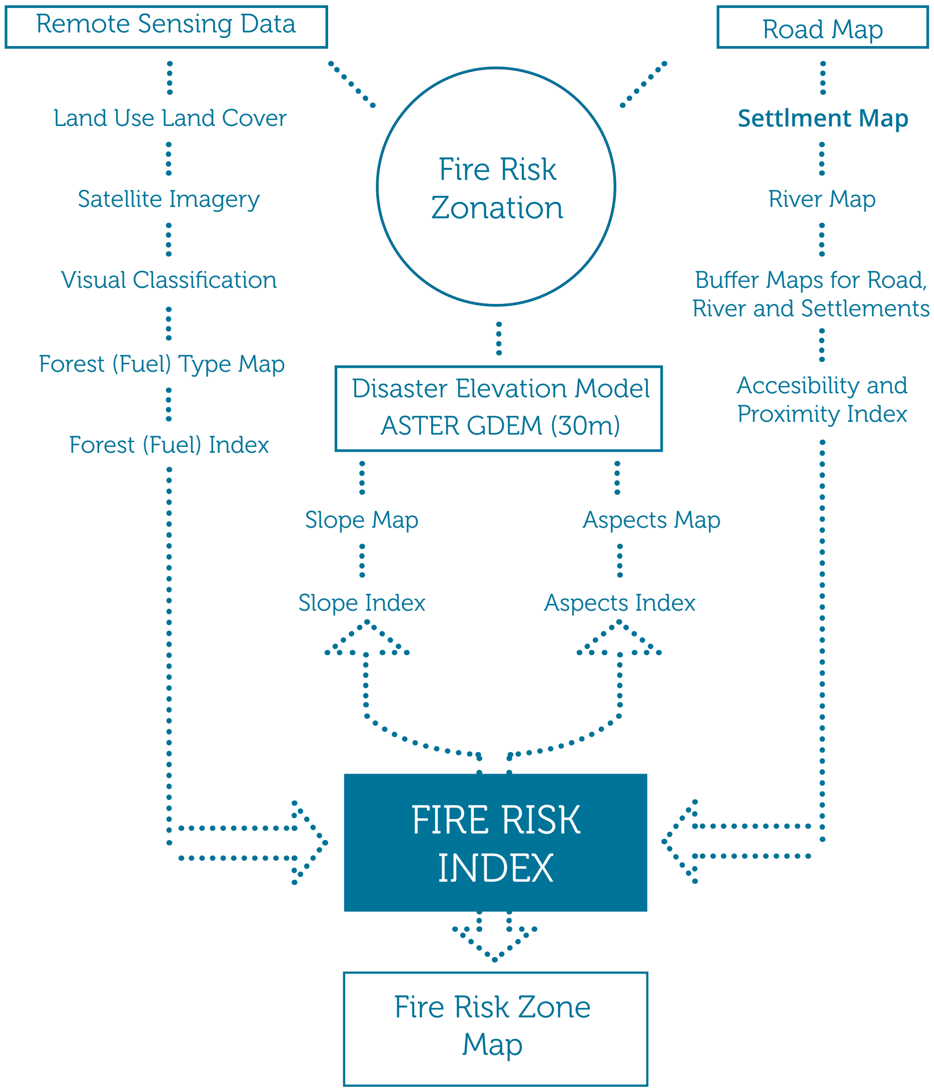


Figure 25: Flowchart explaining the Fire Risk zonation
Source : Chavan et al., 2012, Sharma et al., 2009

These comparison matrixes, lead to priority vector, which are the weights for respective layers. These priority vectors propagated through the hierarchy to get the final priority vector and thus the weights. The methodology consisted of four different components:

- Hierarchical structure development of fire risk criteria,
- Weights determination at different levels of hierarchy using linguistic variables and fuzzy sets,
- Assigning criteria weights in GIS, and
- Fire risk quantification using decision rule.

Forest fire depends on multiple factors with varying influence. Different physical parameters have different characteristics, which contribute to either the ignition of fire or its spread. Some parameters play more significant role then others in forest fire. Therefore, in modeling these parameters are to be considered but assigned weightage according to their contribution.

In this study, physical parameters that were considered for modeling included elevation, slope and aspects, vegetation type, proximity and accessibility parameters such as access to road and water bodies. The integration of these factors was done using a hierarchical approach. Assumptions were made so that every layer has valid points and its influence is quantified.

The hierarchical structure for quantifying fire risk was designed based on the analytical hierarchy model as indicated by Saaty (2000).

Vegetation Parameters

Vulnerability of the forest to fire hazard has been mapped based on vegetation type (land cover). Vegetation is also well known as fuel in forest fire risk assessment. Fuel index plays a very important role in fire risk assessment, which is generally derived from fuel type, and fuel load (Chavan et. al. 2012). Vegetation was considered as a key parameter for classification because some vegetation types are more flammable than others, thereby increasing the fire hazard. Fuels represent the organic matter available for fire ignition and combustion (Rothermel 1983; Albini 1976). In this study, land cover (forest type) has been used as a vegetation parameter.

In this study, vegetation type was derived from Landsat and Global Land Cover (GLC, 2000) data (fuel type). For the present study fuel type was considered as a main factor that affects the spread of forest fire. Fuel type accounted for the over storey (canopy cover) and fuel load for the under storey vegetation as they represent the total fuel available for fire.

Topographic Parameters

For the past several years, fire behavior models have incorporated the interaction of fire spread with fuels, weather, and terrain (Albini 1976; Rothermel 1983). Some effects were accounted for fire line intensity (Rothermel 1983). Other terrain effects on fire intensity and spread were incorporated indirectly through fuel type and moisture. The terrain attributes that has an effect on the survival of the forest following a wildfire has been assessed by Kushla and Ripple (1997) and others. Three different topographic parameters are explained below, as causative factors of fires; these include elevation, slope, and aspect. Most of these parameters were derived from Cartosat and ASTER GDEM (30 m).

1. Elevation: It is an important physiographic factor that is related to wind behavior and hence affects fire proneness (Rothermel 1983). Fire travels most rapidly up-slope and least rapidly down-slope. Elevation values (in m) for fire pixels have been extracted from ASTER GDEM (30m).

2. Slope: It is an indicator of rate of change of elevation (degrees). Slope affects both the rate and direction of the fire spread. Fires usually move faster uphill than downhill (Rothermel 1983; Kushla and Ripple 1997).

3. Aspect: Describes the direction of the maximum rate of change in elevation between each cell and its neighbors. A slope with an east aspect will get direct sunlight earlier in the day than a slope with a west aspect. Also, a north-facing slope receives less sunlight than a south facing slope. Thus, southern aspects receive more direct heat from the sun, drying both the soil and the vegetation.

In this study, aspect was derived from ASTER GDEM (30m) data. Aspect and exposure are very much related to the rate of fuel drying and spreading of the fire. The direction of the slope determines how much sunlight it receives. South and west slopes receive the most sunlight, and so they are much warmer and drier than north slope, which get the least amount of sunlight. Areas exposed to direct sunlight present the higher degree of fire risk because of higher insolation and it corresponds to the main direction of the wind. The variation in sunlight means that all slopes have different microclimates. Different species and amounts of vegetation grow in the different microclimates. Because north slopes and deep ridges receive less sun, they hold more moisture and so stay green longer and support more vegetation than south slope do. Slope was derived from ASTER GDEM (30m) data. Slope has significant role in spread of fire. A forest fire is oftentimes associated with the slope due to more efficient convective preheating and ignition by point contact. Steep slopes greatly speed up the burning rate and the rate of spread of a small fire. When the head of a fire or a spot from it becomes established on a steep slope, a fast run to the top can be expected. The rate of spread is the relative activity of a fire in extending its horizontal dimensions. Consequently, the steeper the slope, the faster the fire spreads.

Results

The fire hazard assessment followed various steps. Pairwise ranking and their respective weights, which were derived using the AHP, are presented in Table 8.

Pairwise Ranking						
Ranking	Ditance from road	Slope	Aspect	Distance from habitation	Distance from drainage	Land cover
Slope	6.0	1.00	1.20	1.50	2.00	0.857
Aspect	5.0	0.50	1.00	1.25	1.66	0.714
Distance frozm drainage	3.0	0.33	0.60	0.75	1.00	0.429
Land cover	7.0	0.25	1.40	1.75	2.33	1.000
Sum	26.0	2.75	5.40	6.75	9.00	3.857
Pairwise Weights						
Weight	Distance from road	Slope	Aspect	Distance from habitation	Distance from drainage	Land cover
Slope	0.231	0.364	0.222	0.222	0.222	0.222
Aspect	0.192	0.182	0.185	0.185	0.185	0.185
Distance from drain-age	0.115	0.121	0.111	0.111	0.111	0.111
Land cover	0.269	0.091	0.259	0.259	0.259	0.259
Sum	1.000	1.000	1.000	1.000	1.000	1.000

Table 8: Pairwise ranking and their respective weights

1.5.4. Forest Fire Hazard Assessment Equation

To assess forest fire hazard in the state of Himachal Pradesh following equation was used.

Forest Fire Hazard Risk

Slope x 0.248
+
River x 0.057
+
Land cover x 0.414
+
Aspect x 0.153

Final weights with relative importance assigned to each factor are presented in following Table.

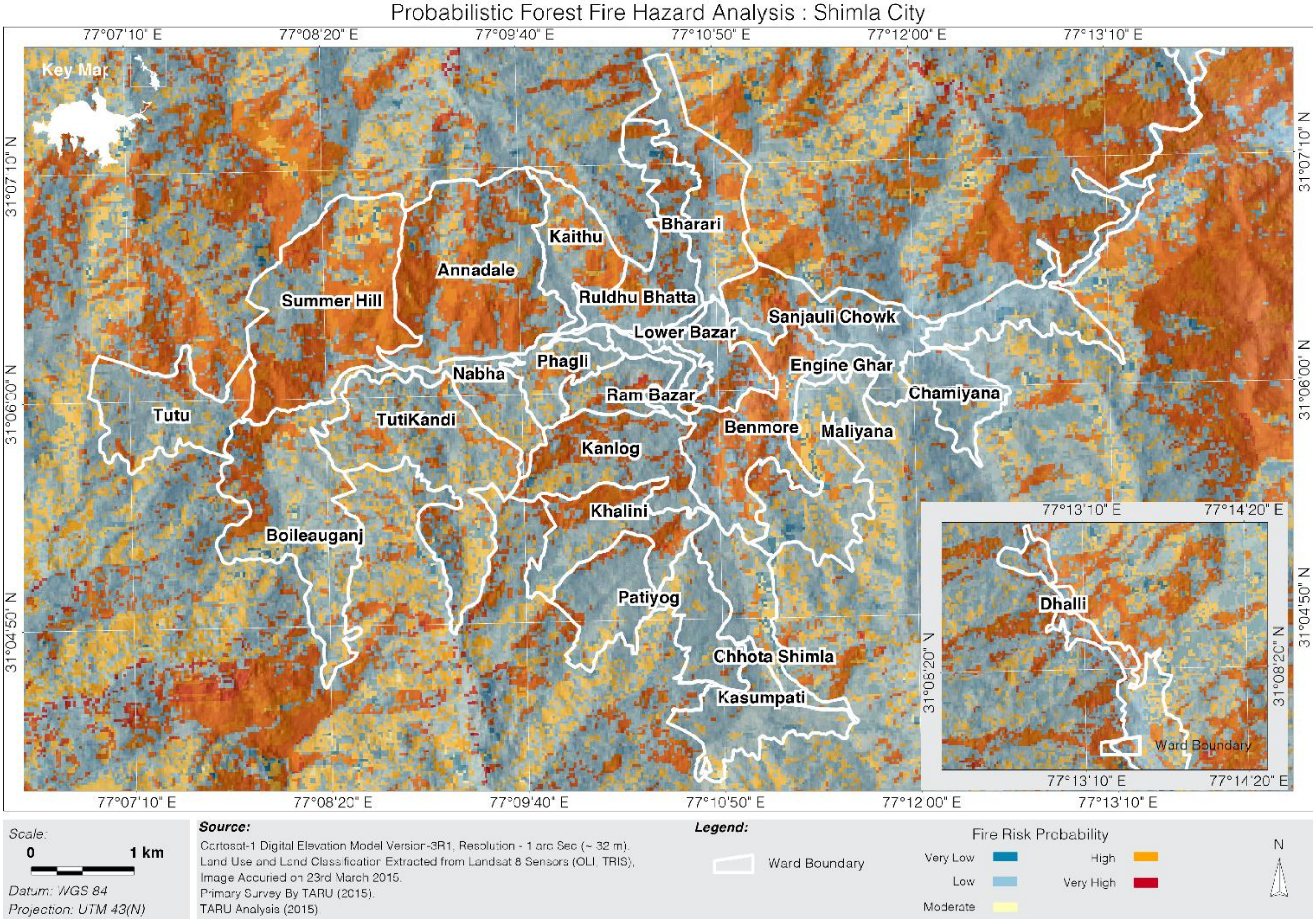
Fire Risk Factor	Relative Importance	Relative Importance Weight
Vegetation (Land Cover)	7	0.414
Slope	6	0.248
Aspect	5	0.153
River	3	0.057

Table 9: Final Weights

Fire Risk Zonation

Fire risk zones were classified (Map 13) into five different categories, viz., very high, high, moderate, low and very low risk zones.

Image 13: Trees on the slopes of Totu forest burn during a forest fire, on the outskirts of the northern Indian hill town of Shimla
Source: anoopnegiphotography.wordpress.com



Map 13: Seismic microzonation for a 2500 year return period (PGA)

1.5.5. Summary

Seismic Hazard Analysis: Seismic hazard of Shimla city shows that eastern part of the city is less hazardous compared to the western part. Seismic activity may not be generated within the city's proximity, however, the Himalayan seismic activity will affect the city. Based on the city's soil profile, much of the city is on either soft or medium soils, which means that the PGA attenuation will be much higher. So a detailed study need to be carried out in order to assess how much PGA each area/ ward will receive. Building byelaws based on the soil depth and soil attenuation will make sure that the building construction follows adequate national building code norms. The inputs from this map can be used as a prerequisite for all the development activities and building construction activities.

Landslide Hazard Analysis: The landslide hazard analysis of Shimla shows that large parts of the city are under moderate to high hazard conditions. While saying this, there are ample signatures of engineering solutions present in the city and its surroundings which point towards the fact that the vulnerability of the area has been identified earlier also and likewise and attempts were made to provide. In most critical slopes of the area retaining walls, cascades have been erected, at most of the places and these are aided with weep holes for transfer of water from higher elevations to the lower elevations without affecting the slopes. Inceptor drains are also ample in the area. However, the interceptor drains are not always properly managed and are in many cases filled with soil, rotting foliage and most alarmingly, plastic which retard and prevent safe carriage of intercepted water. In many places the weep holes have been carelessly stuffed with plastic bottles, which are introducing dampness to the slopes and increasing the degree of hazard. For the safety of slopes it is imperative that the existing engineering structures in the city like retaining walls, breast wall, interceptor drains are regularly maintained. Large scale awareness raising may be considered to make the citizens aware and also to utilise them as instruments of safety by engaging them in upkeep and observation of these features. Creation of volunteer groups may help.

Urban Heat effect: In Lower bazar, Bharari, Chamiyana, Tutikandi and Nabha ward, the variation between land surface temperature and Thermal image was < 2 degree celsius. On comparison of the LST values with the thermal surface, it was observed that the difference of both values in urban area is less than forested area. Various activities in the city do contribute to formation of heat islands within the city. During the summer, the city of Shimla is used to a moderate rise in the temperature. However, the houses are not equipped with the fans or air conditioners. So the effect of higher temperature will accentuate the warm conditions and the same temperature will feel like it is hotter. Ongoing building construction also use glass as a main building material to let more light and heat inside along with reflecting sunlight onto the surroundings. However, this heat that is trapped inside creates uncomfortable conditions indoor. This situation coupled with the rise in summer temperature may cause heatwave conditions in the city. So the city administration need to make provisions for heat shelters, water dispersion units (like the water ATMs) at places highlighted in Figure 56.

Fires: The results obtained through the analytical hierarchical process was quite useful in delineating potential "fire risk" zones at a block level. These maps and results can be used both as a strategic planning tool to address large-scale fire hazard concerns and also as a tactical guide to help managers in designing effective fire control measures at the local level.

The results from the analysis demonstrate the fire potential and possible spread of fire events in the state of Himachal Pradesh. To manage growing forest fires and associated fire hazards, as well as prioritize prescription efforts, it is essential to improve our understanding of the causative factors of fires. Forest fires in the mountainous regions are the result of several underlying factors. In this study, fire risk was quantified in coniferous forests and broad-leaved forests in State of Himachal Pradesh, as a function of topographic, vegetation, climatic, and socio-economic attributes. The criterion maps relating to topographic and biophysical predictors produced in this study can also be used to assess the susceptibility of any vegetation to fire and for determining future fire risks.

In the next chapter elements at risk are explained in detailed.

2

Elements at Risk

2.1 Population

n order to assess the vulnerability of a society, we have created a database of the people and the buildings they are living in. Apart from this a city's capacity also depends on the presence and strength of the institutions which support the city in normal time and in the times of emergency. So in this chapter a detailed database creation has been discussed along with the attributes of the data. One of the main datasets is on population, buildings, infrastructure and economic activities. The same has been described in details below.

Population database has been created from the following sources: 1. Census of India and 2. Primary Survey. Census of India gives data on population in a tabular format, while the primary survey carried out gives the spatial distribution of the population.

The population of Shimla city is 1,69,578 according to the 2011 census. This is distributed among 46,306 households spread over 19 sq km area. The wards Chamyana, Maliyana, Kasumpti, Chhota Shimla and Pateog have higher population as compared to rest of the wards. Ram Bazar, Lower Bazar, Jakhu and Benmore have lower population. The density of the wards is represented in the Map 14.

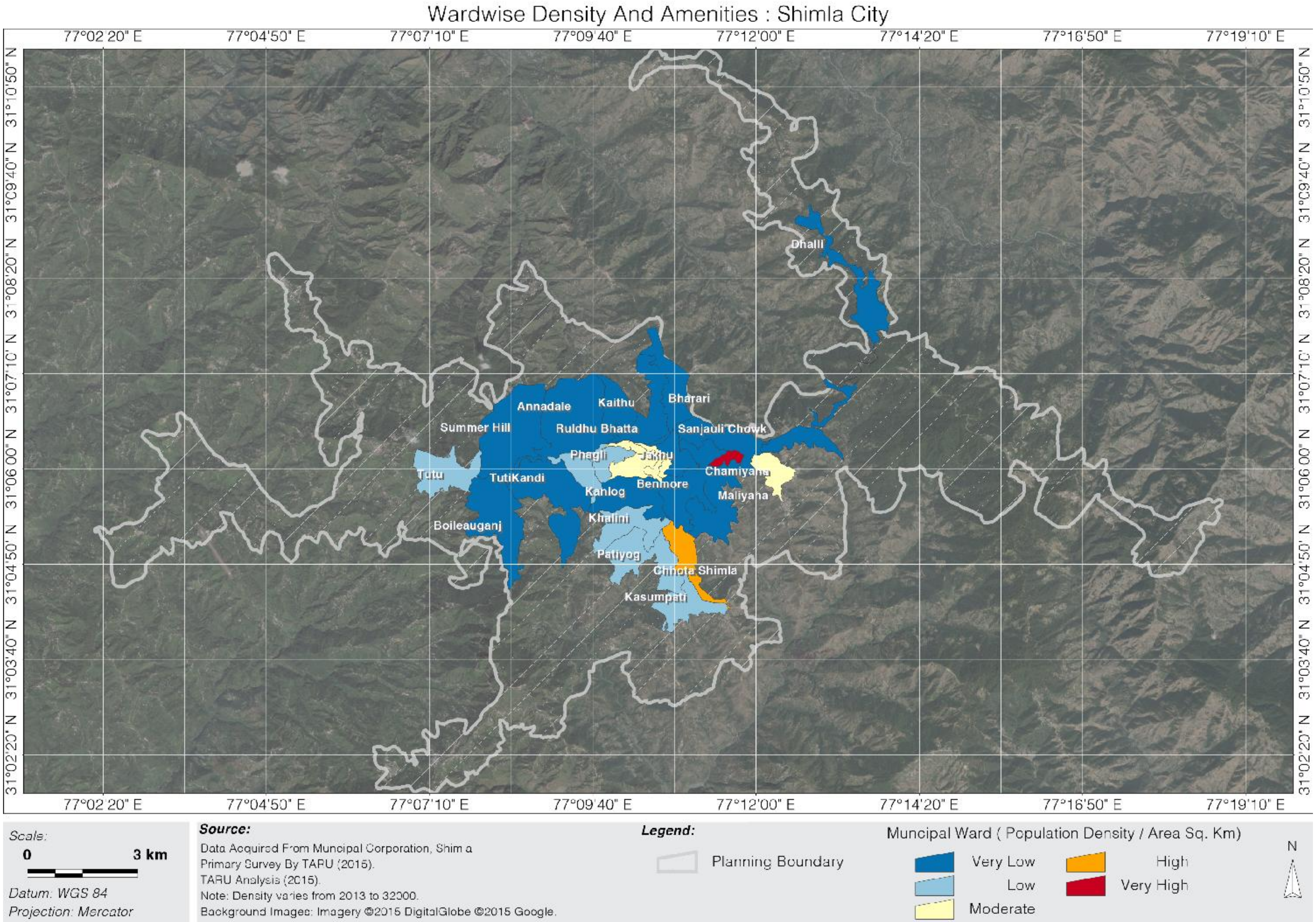
The population density within the wards vary from as low as around 2000 people per sq km in Annadel, Summer Hill and Benmore to, as high as 32000 per sq km in Engine Ghar.

Density is lower in certain wards due to the presence of forest area. Based on the census 2011 data, some crucial parameters of the demography are calculated and tabulated as follows.

No	Name of the ward	No of HH	Total Population	Male	Female	Kids of < 6 yrs age
1	Bharari	1,058	4,113	2,174	1,939	276
2	Ruldhu Bhatta	1,768	6,839	3,797	3,042	563
3	Kaithu	1,093	4,298	2,361	1,937	277
4	Annadale	1,300	4,962	2,682	2,280	434
5	Summer Hill	1,194	5,391	2,478	2,913	387
6	Totu	2,792	9,208	5,118	4,090	804
7	Boileauganj	2,243	8,205	4,543	3,662	690
8	Tutikandi-Badai	1,428	5,361	3,068	2,293	460
9	Nabha	1,324	4,665	2,510	2,155	370
10	Phagli	1,180	4,518	2,622	1,896	356
11	Krishna Nagar	1,671	7,190	4,246	2,944	675
12	RamBazar,Ganj	888	3,734	2,199	1,535	227
13	Lower Bazar	866	3,936	2,569	1,367	188
14	Jakhu	953	3,505	1,856	1,649	210
15	Benmore	958	3,988	1,983	2,005	218
16	Engine Ghar	1,441	5,196	2,724	2,472	433
17	Sanjauli Chowk	1,777	6,526	3,685	2,841	535
18	Dhalli	2,004	7,327	3,952	3,375	645
19	Chamyana	2,986	9,627	5,098	4,529	783
20	Maliyana	2,834	9,884	5,331	4,553	855
21	Kasumpti	2,587	9,185	5,092	4,093	768
22	Chhota Shimla	4,432	15,399	8,424	6,975	1,230
23	Pateog	3,472	12,029	6,572	5,457	1,069
24	Khalini	2,414	8,456	4,931	3,525	671
25	Kanlog	1,643	6,036	3,137	2,899	447

Source : Census of India, 2011

Table 10: Shimla: ward wise Demographic parameters



Map 14: Pattern in Wards

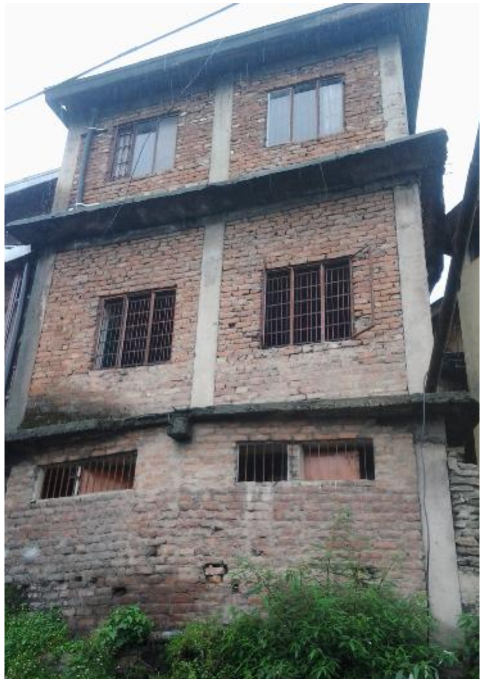
2.2 Buildings

In the city of Shimla, there are a total of 46,306 households as per the census 2011. Majority of the traditional housing has been using techniques of dhajji dewari and kathkhuni (refer Table 11) while the newer buildings are made of reinforced cement concrete (RCC) and brick. A reconnaissance walk around the 25 wards of the city shows a range of buildings from RCC structures to mud structures of varying strength. A thorough investigation has been done on the housing typology and their vulnerability. It has been discussed in details in the section on building vulnerability analysis (BVA).

The built-up area of the city is congested and multistoried brick houses dominate the landscape. The houses have narrow streets and staircases. A significant percentage of buildings in the city are built on unstable slopes. Number of census houses used as residence and residence cum other uses is estimated to be 46,306 (Census of Indz`ia, 2011). 85 % building stock based on wall type in Shimla city are of brick masonry type while the rest are of stone masonry, mud walls and reinforced concrete frame. Apart from the above mentioned building typology, traditional construction type of dhajji dewari can also be observed in the city. This building type has a high seismic resistance due to cross bracing on the wall which prevents the out of plane movement of the wall during earthquake event. However due to poor maintenance their seismic resistance may not be very significant. Based on simple observation, there is an increase in construction of RCC structure type in the city. RCC structures offer greater resistance to seismic shaking, but due to poor handling of materials and less skills in constructing this building type, their ability to withstand severe ground shaking is skeptical.

Due to lack of space, buildings are constructed close to each other and hence they are more susceptible to the spread of fire as well as the pounding effect in case of earthquake. It is observed that buildings constructed on the slope are not provided with requisite measures by stabilizing the slope. Thus buildings located on the uphill side also make the other buildings on the downhill side susceptible to severe damage due to possibility of progressive collapse. The growing demand for housing and the increased migration of people from rural areas and other cities to the capital city of Shimla, has resuled in a lot of building alterations without any formal approval from the competent authority. This has increased the vulnerability of the buildings. Whenever required, upper floors are modified to gain additional floor area without giving attention to the safety consideration of the building. Such modifications have resulted in floating columns and walls which disrupt the proper load path. Increased vertical irregularities of the building can lead to partial or full collapse of the building. The photographic description of these typologies can be seen in the following Image 14.

Hybrid Building



Brick Masonry Building

Image 14: Prevailing Housing Typologies in Shimla Urban areas

R C Frame Building

Dhajji Dewari Construction

Dhajji Dewari Construction

Unburnt Brick/ Mud Construction

Image 14 cont.: Prevailing Housing Typologies in Shimla Urban areas

Following table gives a broad distribution of the housing typologies in each ward. The range of buildings in Shimla can be classified on a vulnerability scale of 1 to 7 based on the materials used and construction techniques being implemented. However, a detailed RVS technique has explained the methods adopted and the detailed vulnerability of these building stock.

No	Ward Name	RC frame	Brick	Stone	Hybrid	Wood	Dhajji Dewari/ Kath khuni	Mud
1	Bharari	60	15		20		5	
2	Ruldhu Bhatta	10	20	5	30	15	10	10
3	Kaithu	60	15		20		5	
4	Annadale	85	15					
5	Summer Hill	60	15	10	5	3	7	
6	Totu	65	20		5		10	
7	Boileauganj	60	15	10	5	3	7	
8	Tutikandi-Badai	50	30		20			
9	Nabha	50	30		20			
10	Phagli	50	30		20			
11	Krishna Nagar	50	25		10	10		5
12	RamBazar, Ganj	40	20	10			30	
13	Lower Bazar	20	30	10			40	
14	Jakhu	85			15			
15	Benmore	30	10	10	40	10		
16	Engine Ghar	60	20		15			5
17	Sanjauli Chowk	50	25	5	5	5	10	
18	Dhalli	80	10		10			
19	Chamyana	60	15	10	10		5	
20	Maliyana	70	10	10	5		5	
21	Kasumpti	45	30		15	5	5	
22	Chhota Shimla	45	30	20	5			
23	Pateog	80	10		10			
24	Khalini	50	25	10	10		5	
25	Kanlog	70	15	5	5		5	

Source : Primary Survey, TARU 2015

Table 11: Shimla: ward wise Demographic parameters

2.3 Infrastructure

In case of any major disaster, how the society copes depends to a large extent on the resilience of the infrastructure. A description of all the identified network based infrastructure has been mapped and database has been prepared in order to understand the vulnerabilities of the same.

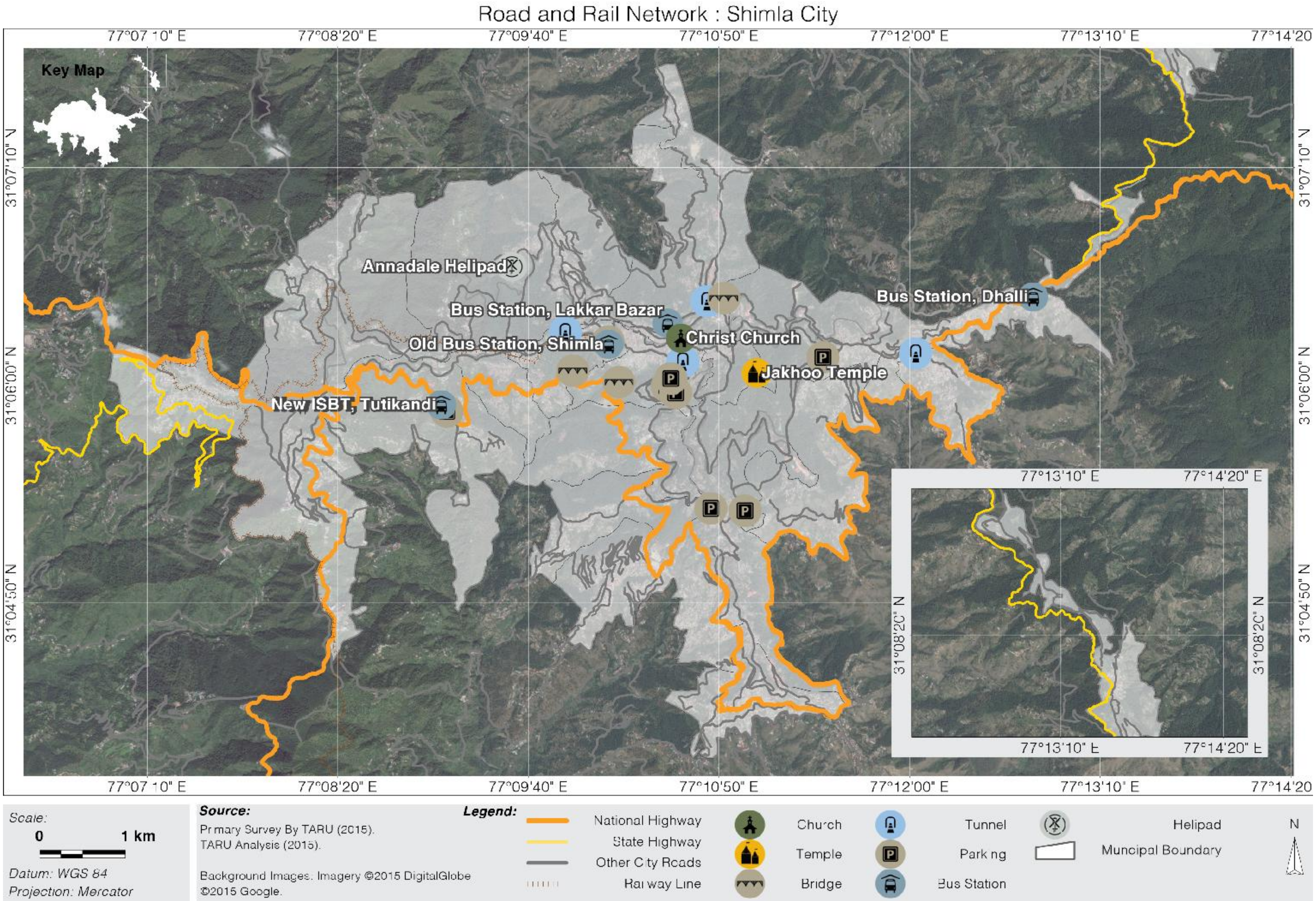
2.3.1 Road Network

City of Shimla has a good amount of roads to cater to all the areas of the city. Main arterial road of the city, NH-22 passes through the central part of the city. However, to reduce the congestion in this particular part of the city, a by-pass has been constructed in the southern part. Vulnerability of the road network within the city is discussed in the section on vulnerability of infrastructure. The existing road network of Shimla city is shown in the following Map 15.

City of Shimla has a good amount of roads to cater to all the areas of the city. Main arterial road of the city, NH-22 passes through the central part of the city. However, access roads in the city are also very narrow and winding making it difficult for the emergency services to access the houses.

Access roads in the city are also very narrow and winding. Motorable roads are very limited. Lines of vehicles parked along the streets outside the neighbourhoods is a very common phenomena in Shimla. In terms of the accessibility, it is also observed that the emergency services also find it difficult to access the houses and vice versa. Detailed analysis of ambulance service and fire services has been carried out and many parts of the city are very difficult to be serviced.

Image 15: Status of access roads in Totu



Map 15: Road and Rail Network of Shimla City

2.3.2 Water supply

Water supply system of Shimla was initially established in the year 1875 to serve a population of 16,000. It was designed to pump water from the nearby stream with the help of engineering structures. Today, water supply is one of the major impediments in the growth and development of Shimla. It is the joint responsibility of Irrigation and Public Health Department (I&PH) and Municipal Corporation Shimla (MCS) to supply drinking water to the population. Whereas, the I&PH department is responsible for the planning and distribution of bulk water in the city, operation and maintenance of water supply infrastructure, billing, collection of user charges and penalties for domestic as well as commercial connections are under the jurisdiction of MCS. The water supply system in Shimla was introduced in 1875 by the British with 4.45 MLD capacity. To mitigate the increased water requirement of city dwellers, Shimla had five water augmentation schemes, 3 before independence and 2 after independence. The last augmentation scheme for the city was commissioned in the year 1992.

Water Sources

Shimla depends on 6 water sources for its daily water needs. The following are the details of water sources.

Water from the above mentioned sources is treated and stored in reservoirs before it is supplied to various zones (Table 12). The location of these reservoirs is vulnerable based on the geological location. When these locations are overlaid on the earthquake microzonation, we understand which are the vulnerable and critical reservoirs.

Source: https://himachalwatcher.com

Image 16: A view of Ashvani Khad Reservoir

	Source Name/ Name of the River	Transmission Type	Year of Commissioning	Installed Capacity (MLD)	Quantity of Water Produced (MLD)	Supply to SMC (MLD)	
						Non Lean Period	Lean Period
1	Dhalli Catchment Area	Gravity	1875	4.54	1.80	0.23	0.20
2	Cherot/ Jagroti Nallah	Pumping	1914	4.80	3.86	3.86	2.65
3	Chair Nallah	Pumping	1914	2.50	3.00	2.50	1.42
4	Nauti Khad (Gumma)	Pumping	1924 & 1982	24.06	19.75	24.06	16.80
5	Ashwani Khad	Pumping	1992	10.06	10.80	10.80	6.30
6	Tube Wells –10 nos.						2.63
	Total Supply			**45.96**	**39.21**	**41.45**	**30.00**

Table 12: Sources of Water for Shimla City and their capacities

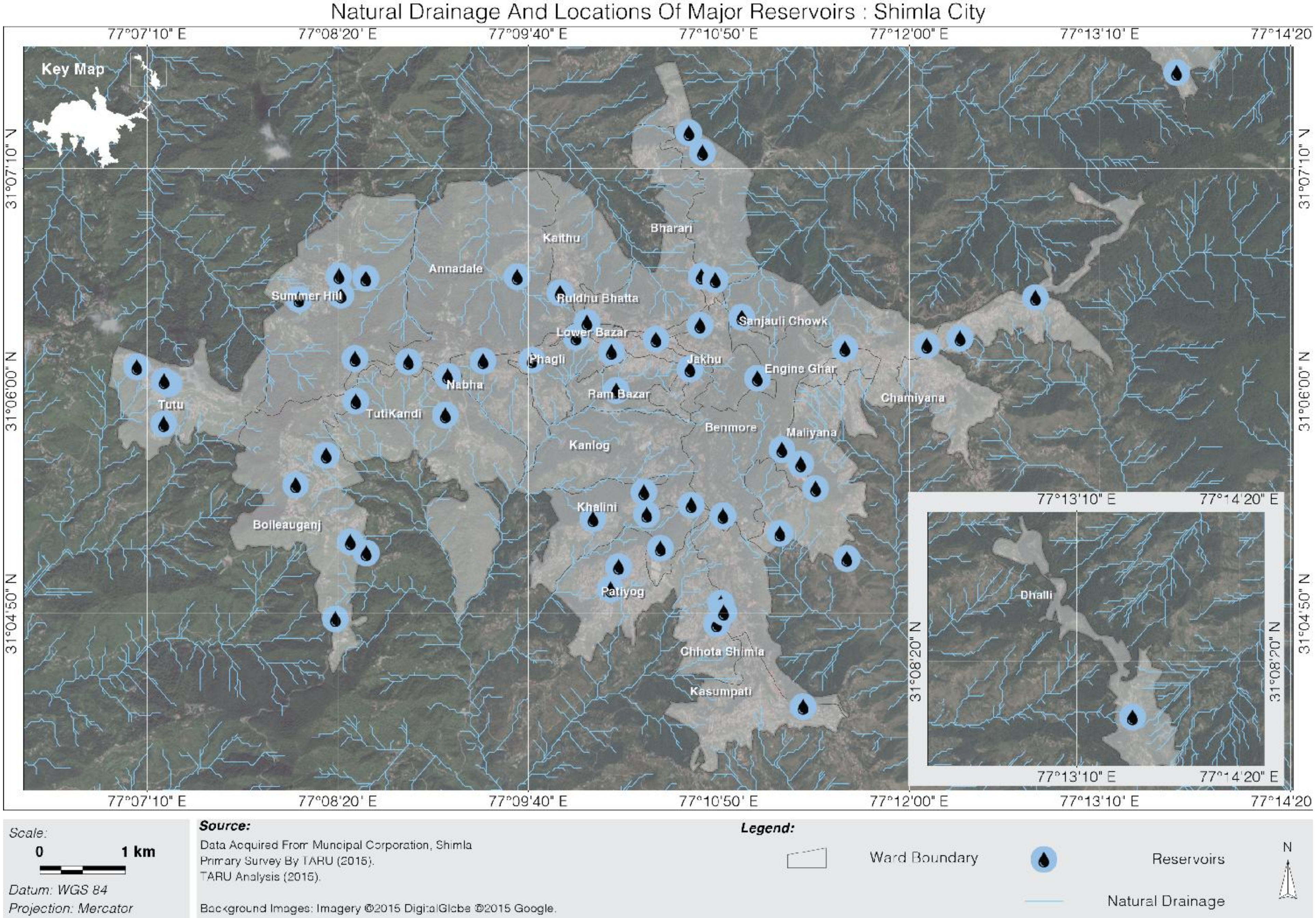
No	Location	Capacity (ML)	Zones Served
1	Sanjauli reservoir	8.78	All zones
2	Ridge Reservoir	4.63	Ridge, A.G. Office, Vice Regal, University, Kamna Devi, Chakkar and Tutu
3	Mains field	3.63	Mains field, High Court, BCS and Kasumpati
4	Mashobra	3.00	Mashobra
5	Jakhu tank	0.13	Sanjauli and Ridge
6	Phagli	0.13	Phagli
7	Jakhu	0.45	Sanjauli and Ridge
8	Shiv Puri	0.045	Mains Field
9	New Shimla Sec-I	0.023	Kasumpati
10	New Shimla Sec-ii	0.023	Kasumpati
11	New Shimla Sec-iii	0.136	Kasumpati
12	Vikas Nagar	0.136	Kasumpati
13	Vikas Nagar	0.136	Kasumpati
14	Kasumpati	2.043	Kasumpati
15	New Shimla Sector-iv	0.30	Kasumpati
16	Dhinghu Mandir	0.30	Dhalli and Sanjauli
17	North Oak (O.H)	0.05	Sanjauli
18	North Oak (U.G)	0.10	Sanjauli
19	Engine Ghar, (Sanjauli)	0.30	Sanjauli
20	Bharari	1.20	Bharari
21	Tuti Kandi (Near tunnel 103)	0.90	A.G. Office
22	Kamna Devi	0.30	Kamna Devi
23	Kelston	0.30	Bharari
24	Corner House	0.30	Sanjauli
25	Knolls Wood	0.90	B.C.S
26	New Shimla Sector-iii	0.60	Kasumpati
27	Tara Mata Mandir New Shimla	0.30	Kasumpati
28	Kali Bari-i	0.160	A.G. Office
29	Kali Bari-ii	0.160	A.G. Office
30	Sandal Chakkar	0.90	Chakar
31	IIAS.(Summer Hill)	0.90	University
32	Totu (Yet to be taken up)	1.60	Tutu
	Total	**33.13ML**	

Table 13: List of Water Supply Reservoirs and the zones they are serving

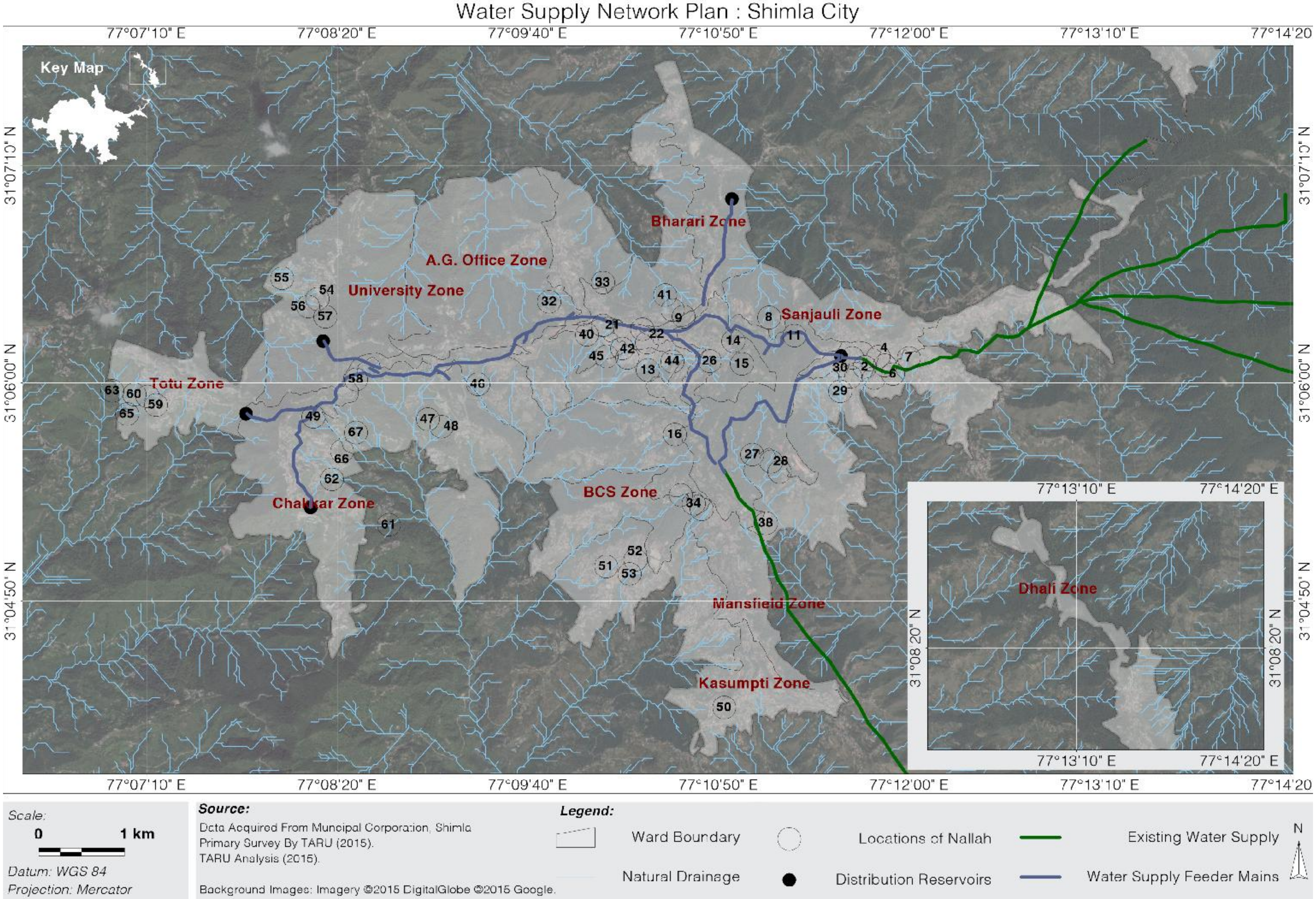
The areas covered under these zones are also identified as below.

- **Sanjauli**: Sanjauli Bazaar, Nav Bahar, Jakhoo, Snowdon, Scandal, Sanghti, Shankli, Grand Hotel.
- **Bharari**: Bharari, Harvington, Kuftu Anu Bermu.
- **Ridge**: Telegraph Office, Krishna Nagar, Subzi Mandi, Ripon, Lalpani, Western Command, Ram Bazaar, Middle Bazaar.
- **High Court**: Lower High Court area, Parasdass Garden, Kanlog, Talland.
- **BCS**: Khalini, BCS, Forest colony.
- **AG. Office**: Kaithu, Annandale, AG. Office, Ram Nagar, Vidhan Sabha, Chaura Maidan, Tuti Kandi, Kumar House, Raj Bhawan, Ava Lodge, Labour Bureau, Kennedy House, Win Gate.
- **Vice Regal Lodge**: IIAS, Tilak Nagar, Ghora Chowki, Hanuman Temple.
- **Mansfield**: Mansfield to Marina, Secretariat, Chotta Shimla Bazaar, Brock Hurst upto Government School.
- **Kasumpati**: Kasumpati colony, Lower Brock Hurst, Patti Rehana, Patina, Mehli, Panthaghati, Pateyog.
- **University**: University Complex, Summer Hill, Govt. Quarters, Shiv Mandir.
- **Kamna Devi**: Hill Spur of Kamna Devi, Forest Colony.
- **Chakkar**: Sandal Hill, Tara Devi, Shoghi.
- **Totu**: Totu Bazaar, Jutogh, Dhamida, Fatenchi.
- **Dhalli**: Dhingu Devi Mandir, Dhalli Bazaar, Inder Nagar.
- **Mashorba**: Mashobra Bazaar, Craignano, Retreat, Jungle Mashobra Sipur.
- **Kufri**: Kufri bazaar, Holiday Resort Complex, Wild Flower, Chinni Bungalow, ITBP Colony, Fair Lawns.

Following map shows the layout of the reservoirs and the water supply zones (16 nos.) as described above.



Map 16: Location of Reservoirs



Map 17: Water supply zones

2.3.3 Sewerage Network

Due to the undulating terrain of the city, only 65% area is covered by piped sewerage system. Though the sewage system in Shimla was initiated in 1880 by the British, it has been maintained and run by the Municipal Corporation and in some areas by Irrigation and Public Health. The sewerage is carried through GI pipes to five disposal sites namely- Lalpani, Kasumpati, North disposal, Snow down and summer hill. The total length of sewerage network was 49.5 kms. The old network was tapped at every possible point and connected to the newly laid sewerage network. As of today the total length of sewer systems is 222 kms which covers approximately 65% of the city area.

Network

The whole city is divided into 6 sewerage zones, the details of sewerage zones and sewer networks are mentioned on right.

Treatment and Disposal

The waste water generated in the city is being treated at six sewerage treatment plants (STPs). The details of STPs are given in the table below.

No	Sewerage Zone/ Name of STP	STP Capacity (MLD)	Treatment Technology	Average Flow (MLD)	Peak Flow (MLD)
1	Lalpani	19.35	UASB followed by extended aeration	1.25	2.56
2	Summer Hill	3.93	Extended Aeration	0.164	0.285
3	North Disposal	5.80	Extended Aeration	0.57	0.145
4	Dhalli	0.76	Extended Aeration	0.53	1.061
5	Sanjauli-Maliyana	4.44	Extended Aeration	1.25	2.41
6	Snowdown	1.35	Extended Aeration	0.10	0.145
	Total	**35.63**		**3.664**	

Source : MCS, I& PH & CSP

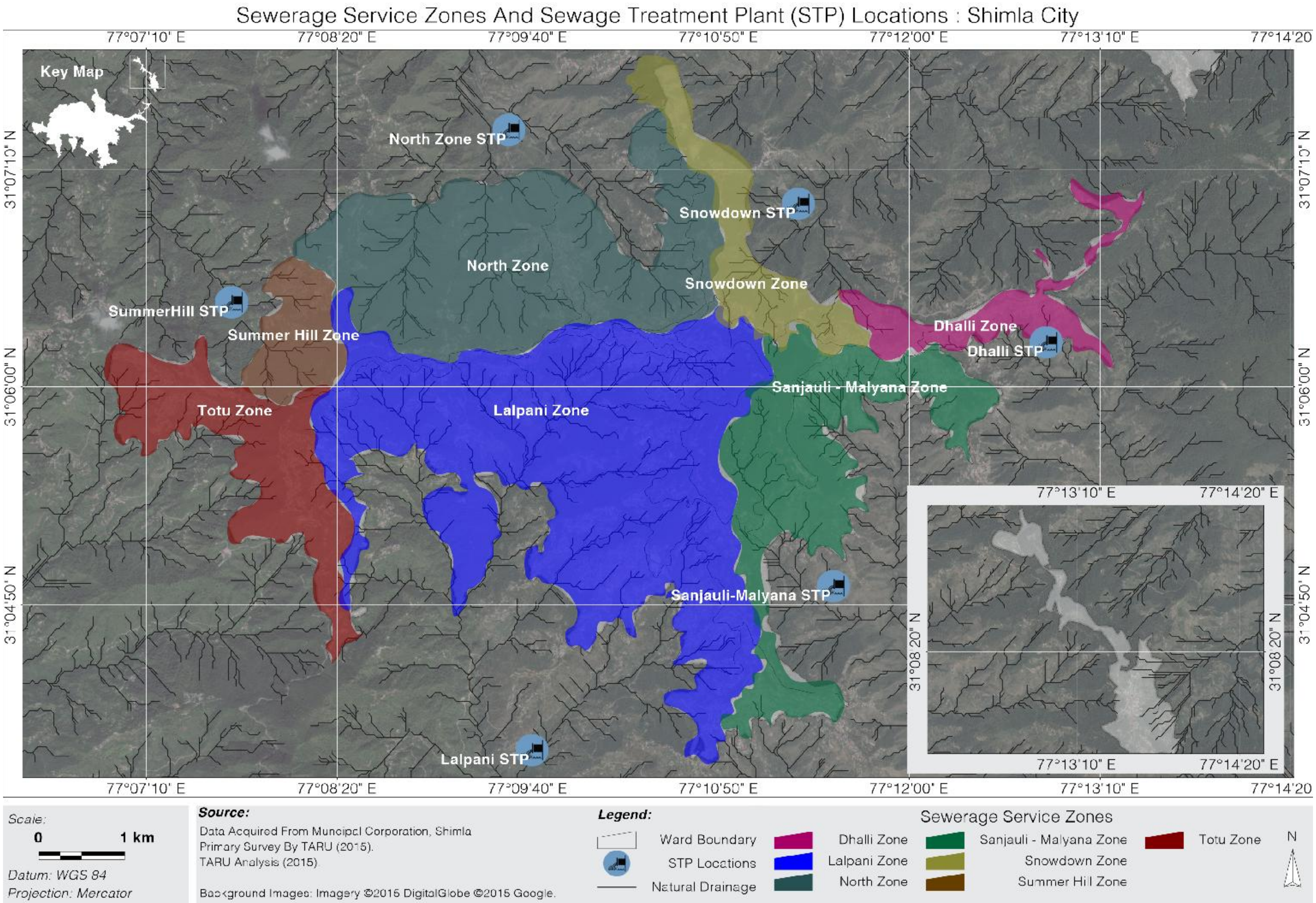
Table 14: Details of STPs

The map below shows the location of these STPs and their service zones.

The sewerage treatment plants have been installed along the main natural drainage system, so that the treated water can be released back into the natural drains.

No	Sewerage Zone/ Name of STP	Areas Covered	Sewer Network (in mtrs)	% Area Covered
1	Lalpani	Ridge, The Mall, Lower and Middle Bazaar, Bus- Stand, Winter field, Jakhoo, US-Club, High Court, Bemloi, Western Command, Nabha, Phagli, RamNagar, Chaura Maidan,Tutikandi, Chakkar, Boileauganj, Lalpani, Krishna Nagar, Kasumpati, Panthaghati, Ghora Chowki, Khalini upper and lower, Nigam Vihar	91,649	50%
2	Summer Hill	Summer Hill, Part of HP university, Part of boileauganj, Tutu, Part of Institute of advanced studies, Chally, Gadwag	16,887	72%
3	North Disposal	HP University (Part) Annadale, Kaithu Sangti, Lakkar Bazaar, Tara hall, Below Kali Bari, Chaura Maidan, Goodwood estate, Kelston (part), Police line, Glene Kumar House, Bharari, Dudhali, Karog, Ghannaghatti	45,222	55%
4	Dhalli	Dhalli, Part area of tunnel, Bhattakuffar, Dhalli, Water Plant, Inder Nagar, Himgiri Colony, Chhakrayal	11,373	50%
5	Sanjau-li-Malyana	Sanjauli, Chotta Shimla, Panthaghatti, Malyana, Part of Kasumpati, Parimahal, Basant Vihar, PWD colony, Nav Bahar, Indus Hospital area	43,480	54%
6	Snow down	Medical college complex, Military Hos-pital, Longwood	12,614	56%
	Total		**221,225**	

Table 15: Sewerage collection zones and the areas covered



Map 18: Sewerage Zones and the STP locations

2.3.4 Storm Water Drainage

The city owing to its geographic location is blessed with a hilly terrain and steep slopes which gives it a natural drainage system. The rainfall in the hilly areas is channelized through natural open streams and nalah to downstream areas. The surface run off finds its way to natural nalah and drains and thus the problem of water logging is minimal. The main spinal ridge is a drainage divide of Shimla city. The tributaries and streams on the southern side of the ridge drains into the catchment of river Yamuna and those on the northern side of the ridge drains into River Satluj. Shimla city has 67 natural drains, also referred colloquially as nalahs (including major and minor drains). Some of these drains are also carrier of wastewater and solid waste.

The retaining walls that line many of the local city roads, have 'weepholes' that let the seepage of water come out of the landmass and this keeps it stable. However, in many places, these weepholes are being manually filled up with solid waste like plastic water bottles, food package, etc. This has led to many of the weepholes being blocked and the water is retained inside the soil, which may eventually lead to the failure of the slope.

Within the city and on the peripheral areas, many of the natural drainage lines are being disturbed because of the ongoing construction activities. These construction activities disturb the natural drainage in the short term. However, in the longer term, they will eventually become unstable and may cause slides. This issue is further discussed in the landslide hazard zonation. Natural drainage pattern of the study area is divided into two major basins, as mentioned above: Yamuna catchment in the south and Sutlej catchment in the north.

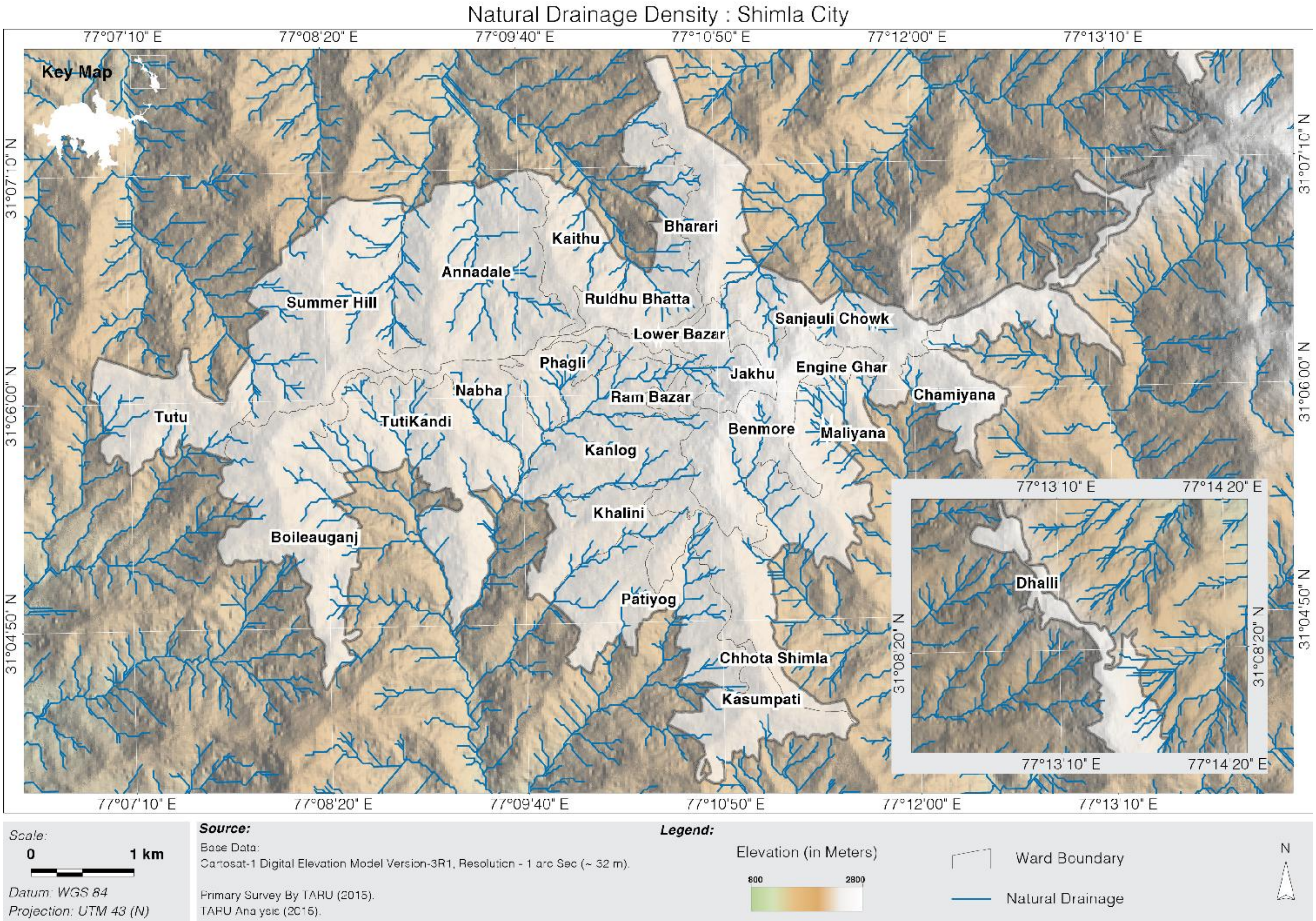
2.3.5 Economic Activities

Shimla owes a lot to the tourists for its economic sustenance. Major contribution to the economy is the spending of the tourists followed by the remittances. Agriculture, though a major activity in employing the majority of the people in the district, doesn't provide the sustenance to the people, owing to its seasonality. The apple orchards which are in the upper reaches of the Shimla district do contribute to large employment, but not to economy. Majority of the Shimla people are placed either in the tourism industry or in the administrative department of Shimla. A vast number of people are working as travel agents, guides, or photographers or working in areas related to the tourism industry like hotels and restaurants. Shimla's economy is being run to a large extent by the tourism industry that has developed gradually over the years. Shimla is the administrative capital of the state of Himachal Pradesh. As such, there are many important departments and offices of the governing body in Shimla. The people working in these offices are the cogs and screws of the economy of Shimla. Shimla being an ideal getaway, the tourism industry in Shimla is booming. The tourism industry has been a major source of income for the people of Shimla. The overall scenic beauty of Shimla with the rolling hills and salubrious climate attracts domestic as well as foreign tourists.

Indicator	2012-13	2013-14	2012-13	2013-14
GSDP in Cr	Absolute value		% Change over previous year	
(a)At current prices	76259	85841	14.8	12.6
(b)At constant prices	44610	47376	6.2	6.2
Food grains production (lakh tonnes)	15.41	15.76	(-) 0.2	2.3
Fruit production (lakh tonnes)	5.56	8.66	49.1	55.8
Gross Value Added from in-dustrial sector (in Rs.Crore) at constant prices	15402	15795	15.6	2.6
Electricity generated (Million Units)	1815	1951	(-) 4.7	7.5
Wholesale Price Index	167.6	177.6	7.4	6
C.P.I. for Industrial Workers (HP)	193	213	10.3	10.4

Source : Economic Survey of Himachal Pradesh, 2014-15

Table 16: Economic indocators of Shimla



Map 19: Natural drainage pattern in Shimla

Physical manifestation of these economic activities in the city are: banks, industries, restaurants, hotels, market yards, warehouses, informal markets, etc. These are also linked with other infrastructure like LPG godowns, food warehouses, ATMs, which may, in case of a disaster incur damage/loss. So these elements are also mapped.

Category of Industry	No. of Units	No. of Work-ers	% of Total Workers
Food-based industries	30	123	15%
Textile	16	39	5%
Leather	6	5	1%
Wood and wood works	40	137	16%
Paper and paper products	22	80	9%
Other manufacturing, industries and services	145	460	55%
TOTAL	**259**	**844**	**100%**

Table 17: Distribution of industries in Shimla

2.3.6 Summary

The population of the city of Shimla is distributed among 46,306 households spread over an area of 19 sq kms. The population density within the wards vary from as low as around 2000 people per sq km in Annadel, Summer Hill and Benmore, to as high as 32000 per sq kms in Engine Ghar. Density is lower in certain wards due to extensive forest areas.

A significant percentage of buildings in the city are built on unstable slopes. Based on simple observation, there is an increase in construction of RCC structure type in the city. They offer greater resistance to seismic shaking but due to poor handling of materials and less skills in constructing this building type, their ability to withstand severe ground shaking is skeptical. Due to lack of space, buildings are constructed close to each other and hence they are more susceptible to the spread of fire as well as the pounding effect in case of earthquake. Increased vertical irregularities of the building can lead to partial or full collapse of the building.

In case of any major disaster, how the society copes depends to a large extent on the resilience of the infrastructure such as the road network, water supply, sewerage network, etc. Today, water supply is one of the major impediments in the growth and development of Shimla. Whereas, the I&PH department is responsible for the planning and distribution of bulk water in the city, operation and maintenance of water supply infrastructure, billing, collection of user charges and penalties for domestic as well as commercial connections are under the jurisdiction of MCS. To mitigate the increased water requirement of the city dwellers, Shimla had five water augmentation schemes, 3 before independence and 2 after independence. This water however is stored initially in reservoirs before they are distributed to the various zones.

The location of these reservoirs is vulnerable due to its geological conditions. Overlying of these locations on the earthquake micro zones helped understand the vulnerable and critical reservoirs. Due to the undulating terrain of the city, only 65 % area is covered by piped sewerage system. The city owing to its geographic location is blessed with a hilly terrain and steep slopes which gives it a natural drainage system. Within the city and on the peripheral areas, many of the natural drainage lines are being disturbed because of the ongoing construction activities. These construction activities disturb the natural drainage in the short term. However, in the longer term, they will eventually become unstable and may lead to landslides.

Agriculture, even though is the activity that employees majority of the people in the district, it fails to provide sustenance to the people, owing to its seasonality. Shimla is the administrative capital of the state of Himachal Pradesh and there are many important departments and offices of the governing body in the city. In addition, the tourism industry has been a major source of income for the people of Shimla. Physical manifestation of these economic activities in the city are: banks, industries, restaurants, hotels, market yards, warehouses, informal markets, etc. These are also linked with other infrastructure like LPG go downs, food warehouses, ATMs, which may, in case of a disaster, incur damage/loss.

3

Vulnerability Analysis

3.1 Physical Vulnerability

Vulnerability of the population and the building stock are the most exposed features of a city. The vulnerability of these two important elements of the society are assessed. Vulnerability is a condition of susceptibility to withstand an external effect or cope up without (or minimal) support from outside. Social scientists classify vulnerability into two classes – intrinsic vulnerability and extrinsic vulnerability. Intrinsic vulnerability is the inbuilt characteristic(s) of the society, while extrinsic vulnerability is caused because of the extrinsic influences, like landslide, flood, earthquake, etc. For example, the intrinsic vulnerability of a building is determined based on its own structural elements, i.e. strength of the columns, presence of foundation, regular horizontal bands, etc. Lack of which will be the vulnerability of the building. Similarly, for population, it inlucdes the socioeconomic vulnerability of the people, like poor health conditions, illiteracy, poverty, lack of male members in a family, higher share of elderly population or kids, etc. Extrinsic vulnerability refers to the susceptibility of the building to the impacts of any external capable of causing damage. Vulnerability of buildings and people is discussed in following sections.

3.1.1 Building Vulnerability

A popular saying "earthquakes do not kill people, but the coffins they live in, do", precisely highlights the importance of strong buildings and the impact of poor building construction on life and property.

The traditional housing typologies that evolved in Himachal Pradesh have been known for its strength to withstand all natural calamities. However, the latest adoption of building materials and construction practices, are foreign and have been causing problem. RCC is one of the popular roofing materials that is used in all the new constructions in the city. However, there is a lack of trained engineers and masons to execute such work. Masons having the expertise and knowledge of constructing the traditional buildings have adapted themselves to the changing conditions and have become gap fillers in the RCC construction. The labour force for these constructional activities are brought in from the plain areas, who lacks knowledge or experience in managing slopes and dealing with construction in these areas. Table 18 shows the prevalent traditional building typologies and construction practices, where they are more popular. A brief description of the building technology is explained below.

Name of the Building Typology	Districts where it is found
Dhajji Dewari	Shimla, Kangra
Kath Kunni	Kinnaur, Chamba, Lahul and Spiti, Kullu
Thathara	Chamba

Table 18: Traditional Construction Practice in Different Districts of Himachal Pradesh

Source: TARU Analysis 2015

Dhajji Dewari

Dhajji Dewari is a traditional construction type mainly found in Shimla and Kangra districts of Himachal Pradesh. In Indian standard code, it is termed as brick nagged timber frame construction. In this construction technique, timber frame is used as a bracing and the space between frames is filled with brick or stone traditionally and laid with mud mortar (ref Image 17). Completed walls are plastered with mud mortar.

Seismic Behaviour of Dhajji Dewari: At the time of earthquake, masonry infill panels quickly crack in plane and thus absorb the energy through friction against the timber framing and between the cracks in the fill material. Timber frame and closely spaced bracing prevents propagation of large cracks through the infill walls due to their elastic behaviour. Timber bracing provide the robust boundary conditions for the infill material to arch against and thus resist the out of plane inertial loads.

If these houses are constructed carefully with good quality of materials, it can perform well in earthquakes. Dhajji Dewari houses built in Himalayan region performed well in previous earthquakes.

Image 17: Dhajji Dewari Type House

Thatara House

This building type is mostly found in Chamba district of Himachal Pradesh. Locally termed as "Thathara" is used for wooden planks and they are used as vertical load carrying members (ref Image 18). Thathara houses are mostly built in cold regions which witness heavy snowfall in winter season (October to March). These houses have sloping roofs with adequate projection to take care of snow deposition on roof. Mud and wood interiors keep the house warm.

Seismic Behaviour of Thatara Houses: The structural system of this building typology consist of 'Tholas' and wooden beam. Tholas are the vertical load carrying members which are made of stone and Thatharas (plank, log or piece of wood). Generally there is no mortar used in Tholas. Tholas are provided at the corner or ridges of the building and support the horizontal beams which in turn support the inclined rafters and purlins. The structure contains a complete load path for seismic force effects from any horizontal direction that serves to transfer inertial forces from the building to the foundation.

Image 18: Thathara House

Kath-Khuni Architecture

Kath Khuni is very old traditional construction style which evolved more than 100 years ago. Generally long thick log and stone are used as alternate layers of wall material for this kind of structure (ref Image 19). Lot of features of Kath Khuni architecture provide the basis for modern earthquake resistant design, like the alternate layers of wooden log around the wall work as horizontal bands required for masonry construction. Roofs are constructed with slates.

Seismic Behaviour of Kath Khuni Structures: The building configuration provides adequate safety against lateral shear, but there is no apparent safety measure against overturning. The primary structural system mainly consists of wooden elements. If designed and used properly, the wood assemblies offer a high strength-to-weight ratio compared to other modern work materials. This results in low inertia forces during an earthquake.

In order to understand the building vulnerability, a detailed analysis of the buildings was carried out. Table 19 explains the building stock based on the roofing typology in Shimla city. According to the Census of India, majority roof type (about 68%) is that of GI sheet, metal roof or asbestos sheet. This is owing to the local building byelaws which state that all the buildings need to have a slant roof, to drain off the snow from the roofs. Followed by these slant roofs are the reinforced cement concrete (about 28%) roofs. Rest of the roofing systems have only a smaller share as can be seen in the table below.

Image 19: Kath Khuni Architecture

Ward No	Grass/ Thatch/ Bamboo/ Wood/Mud etc.	Plastic/ Polythene	Handmade Tiles	Machine made Tiles	Burnt Brick	Stone/ Slate	G.I./Metal/ Asbestos sheets	Concrete	Any other material
Ward 1	1.2	0	0	0	0	0.4	75.7	22.6	0
Ward 2	2.7	0.3	0.1	0.1	1.7	0.4	62.6	32.1	0.1
Ward 3	3.4	0	1.0	0.3	0	3.4	75.4	16.5	0
Ward 4	5.3	0.1	0.4	0.4	0.3	2.0	53.9	37.7	0
Ward 5	0	0	0	0.6	0.1	0.3	68.4	30.1	0.6
Ward 6	0.2	0.6	0	0	0	0.6	22.7	75.8	0.1
Ward 7	0.1	0	0.1	0	0	0.2	55.1	44.4	0.1
Ward 8	0.1	0.3	0.1	0	0	0.4	73.9	25.3	0
Ward 9	0	0.8	0.3	0	0.1	0.2	91.4	7.1	0
Ward 10	1	1.3	0.2	0	0	2.4	75.1	20.0	0
Ward 11	1.3	0	0.3	0	0.3	0.6	50.2	47.3	0.1
Ward 12	0.1	0.1	8.3	0	0.2	0.1	89.1	1.9	0.1
Ward 13	2.4	0.4	0.1	0.3	0.8	1.1	91.9	2.7	0.3
Ward 14	0.3	0	0.2	0	0	0.8	86.8	11.0	0.8
Ward 15	0.7	5.4	0	0	0.1	1.5	88.3	3.7	0.3
Ward 16	0	0.8	0	0	0	5.0	79.8	13.9	0.5
Ward 17	0.1	2.6	0.1	0	2.2	0.5	65.9	28.8	0
Ward 18	0.5	0	0	0	0.3	0.8	68.0	30	0.4
Ward 19	0.3	0	0.1	0.2	0.7	2.2	48.8	47.7	0.1
Ward 20	0.7	0	0.2	0.1	0.2	3.9	53.3	41.6	0
Ward 21	0.3	0.1	0.1	0	0	0.8	67.9	30.8	0
Ward 22	0.2	0	0.1	0	0.1	0.9	60.8	37.8	0.1
Ward 23	0.6	0.3	0.5	0.1	0.2	1.2	52.6	44.4	0
Ward 24	0.7	0.1	0	0	4.0	1.1	54.9	39.2	0
Ward 25	3.1	0.4	1.2	0	0.3	1.2	86.0	7.7	0

Source : Census of India, 2011

Table 19: Shimla - ward wise predominant roof material

Roofing material can play an important role in understanding the building vulnerability. On one hand, it shows the strength and durability, and on the other, it shows the crushing strength of the same. Apart from the roofing material, other aspects of a building which plays an important role are: details of the foundation, structural elements, over-hanging loads, building floor plan, distance between adjacent buildings, presence of horizontal bands, structural configuration and irregularities, age of the building, etc. The building vulnerability survey of 2,795 buildings which was conducted in the city during July – August covered all the important government buildings, public schools and hospitals, apart from a selected sample of 1,547 residential buildings.

Dilapidated Stock

Of the 25 wards in Shimla, 2% of the buildings (both residential and non-residential) are already dilapidated. Rest of the stock is either good (80%) or livable (about 18%). In terms of the age of the housing stock in various wards of Shimla, Kaithu, Annadale, Tutikandi-Badai, Phagli and Kasumpti wards have a higher share of dilapidated stock.

Ownership of house

Wards of Nabha, Khalini, Chamiyana and Tutikandi have a higher population of tenants (65%). KrishnaNagar has an equal number of owners and tenants. Wards of Sanjauli chowk, Engine ghar, Boileaugunj, Kaithu and Pateog on the other hand have more percentage of owners than tenants.

Complaints about hazards

As per Table 20, the wards in red colour have a higher mention of the respective hazard and the ones in blue shade have a lower mention compared to that of the others. For example, in Benmore all the sampled households have complained about hailstorm in the last 5 years, whereas in Bharari, more than 60% of the households did not face the problem. Similarly, not many households have complained about urban/domestic fires (only a max of 15% in ward Lower Bazar). Landslides and sink zones are observed in many parts of the city. The central column explains about the landslides around the wards. Summer Hill, Totu, Boileauganj and Tutikandi-Badai wards have a higher share of households complaining about landslides.

From a sample survey of 2,795 buildings across the city, majority (2,204) are residential buildings. Commercial, educational, government and institutional buildings are the next largest number in the sample. Apart from these, 33 large

Ward No	Name of the ward	Hailstrom	Landslide	Urban Fire
1	Bharari	63.2	42.1	0.0
2	Ruldhu Bhatta	50.0	28.0	2.4
3	Kaithu	71.4	36.5	0.0
4	Annadale	70.6	45.1	2.0
5	Summer Hill	77.1	55.2	6.3
6	Totu	68.9	48.9	10.4
7	Boileauganj	73.2	51.2	6.3
8	Tutikandi-Badai	94.4	61.1	0.0
9	Nabha	66.7	35.3	13.7
10	Phagli	71.4	20.4	10.2
11	Krishna Nagar	61.7	46.8	4.3
12	Ram Bazar,Ganj	70.6	23.5	11.8
13	Lower Bazar	80.0	10.0	15.0
14	Jakhu	97.3	43.2	0.0
15	Benmore	100.0	43.8	0.0
16	Engine Ghar	52.2	8.7	0.0
17	Sanjauli Chowk	52.9	48.5	2.9
18	Dhalli	94.8	50.5	4.1
19	Chamyana	94.0	48.8	0.0
20	Maliyana	49.5	20.6	11.2
21	Kasumpti	35.3	44.9	0.0
22	Chhota Shimla	85.2	44.4	1.2
23	Pateog	80.1	51.6	3.8
24	Khalini	56.8	26.3	4.2
25	Kanlog	64.2	50.5	7.4

Table 20: Ward wise presence of various hazards

assembly/congregation buildings and 17 emergency related buildings were also covered, in order to understand their intrinsic vulnerability. The details of the same has been provided in Table 21.

Type of building	Number of samples
Assembly/ Congregation buildings	33
Commercial buildings	194
Cowsheds/Gaushala	3
Educational buildings	161
Emergency Services	17
Government buildings	142
Institutional buildings	20
Residential buildings	2,204
Service provider's buildings	21
Total	**2,795**

Table 21: Breakup of building vulnerability sample

Rapid Vulnerability Screening (RVS) methodology was first developed by "Applied Technology Council" in the late 1980's and published in FEMA 154 in 1988. RVS format was, for the first time introduced for masonry buildings in Indian building code in 2009 i.e. IS 13935:2009 "Seismic Evaluation, Repair and Strengthening of Masonry Buildings - Guidelines". This RVS format was designed for earthquake.

RVS is a form of survey to identify the buildings which are expected to be more vulnerable to an earthquake. It is used to prioritize the buildings in a jurisdiction for further evaluation and required retrofitting for seismic forces (CPWD 2007). RVS is designed to evaluate the primary lateral load resisting system and to identify the building attributes that modify the seismic performance of the lateral load resisting system along with the non-structural components. A building may require 15 to 30 minutes for RVS depending upon the size of the building. Data collection and decision making process takes place at the building site.

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HVRA initiative in H.P. took into account the multiple natural hazards such as- earthquake, flood, landslide, avalanche, fire etc. An integrated RVS is needed to evaluate the vulnerability of the buildings for multiple hazards. For this project, RVS was an inbuilt section of the whole building vulnerability assessment process. Some of the parameters that have been used to calculate the RVS score are explained below.

Parameters for performance score evaluation

Parameters selected for computing the RVS score or performance score are described in details in this section. Some parameters such as number of floors, type of seismic zone, soil condition, pounding effect and apparent quality of structure, are similar for the computation of RVS score for both RC frame and brick masonry building. Other parameters for RC frame include frame action, soft storey, vertical and plan irregularity, short column and heavy overhang. For brick masonry structures, other parameters such as structural irregularities, wall opening, wall orientation, horizontal bands, arches and diaphragm action are also taken into account.

Number of Floors

This refers to the total number of floors above the ground level. The buildings were generally residential, although some were commercial and some had mixed use. Mixed ones are those which has residential accommodations above the ground floor commercial premises.

Structural Irregularities

Properly distributed lateral load resisting elements within the building leads to a regular structural configuration and better seismic performance. The structural walls should be uniformly distributed in both the orthogonal directions of the building. They should be sufficient in number and strong enough to resist the expected seismic loads. In masonry buildings, horizontal vibrations can be most damaging, especially in situations where adequate walls are not present in both the orthogonal directions, or when the walls are not properly joined to the adjacent walls. Low income residential areas, having small and narrow plots for the houses may have two parallel walls in one direction only, with fewer walls in the perpendicular direction. Deep plots located in commercial areas, having comparatively narrow frontages, it is quite common in India to find buildings with walls only at the two ends along the long directions and no walls in the other direction, to accommodate clear floor space for display or storage. Such buildings are clearly very vulnerable. Figure 38 shows the presence of structural irregularities in the building.

Heavy Overhangs

Heavy overhangs are formed when projections of the actual habitable spaces from the first floor upwards, are made to increase the available floor area in the upper floor tenements. Buildings having such large and heavy cantilever projections have been observed to sustain heavy damage in the event of earthquakes. Heavy balconies and overhanging floors in multistory reinforced concrete buildings shift the mass center upwards; accordingly giving rise to increased seismic lateral forces and overturning movements during earthquakes. Buildings having balconies with large overhanging cantilever spans, enclosed with heavy concrete parapets sustained heavier damages during earthquakes compared to regular buildings at that elevation. Since this building feature can easily be observed during a walk-down survey, it is included in the parameter set. Large cantilevers (projections supported only on one side) especially in the upper floors are undesirable.

Re-entrant Corners

The re-entrant, lack of continuity or "inside" corner (Figure 26) is the common characteristic of overall building configuration that, in plan assumes the shape of an L, T, H, +, or combination of these shapes. The dimension of the offset and the proportion of the derived wings will determine the vulnerability of a building. Each wing will react to the displacements and the torsional effects produced by the ground motions in a different way. Each wing has a different dynamic behavior during seismic activities because of its particular stiffness and position, relative to the direction of horizontal forces. The movement of different parts of the building can be very complicated, producing considerable diaphragm deformation, torsional effects and concentration of stress at the vertices of reentrant corners

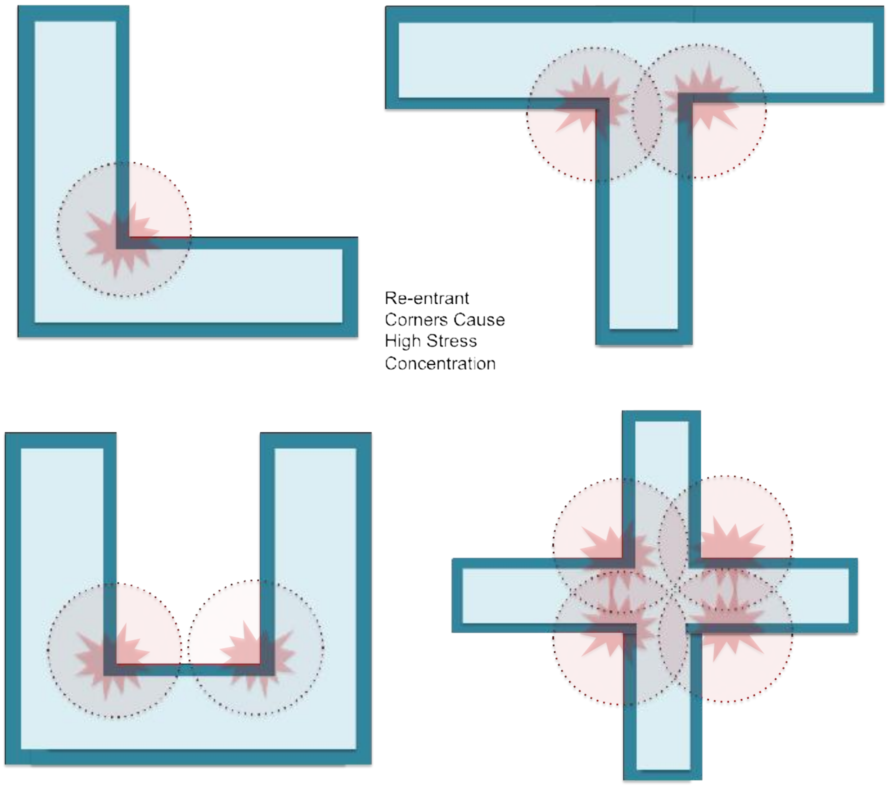


Figure 26: Re-entrant corners in buildings

Local Soil Conditions

The intensity of ground motion at a particular site predominantly depends on the distance of the causative fault and the local soil conditions. There exists a strong correlation between the peak ground velocity (PGV) and the shear wave velocities of the local soil. Site amplification is one of the major factors that increase the intensity of ground motions. Although it is difficult to obtain precise data during a street survey, an expert observer was able to classify the local soils as stiff or soft. The geotechnical data provided by local authorities was a reliable source for classifying the local soil conditions. The risk to the buildings increase with increasing softness of the soil. Sandy soil, saturated with groundwater, has a greater possibility of being impacted by liquefaction during earthquakes, due to the lack of firmness and jelly like characteristics.

Pounding

Pounding refers to the damage caused by two buildings or different parts of a building hitting one another. The number of buildings damaged by pounding is small. It is the result of irregular response of adjacent buildings of different heights and of different dynamic characteristics. In situations where two buildings are located too close to each other, they may collide during strong shaking leading to substantial damage and is particularly more pronounced in taller buildings. When building heights do not match, the roof of the shorter one may pound at the mid-height of the columns of the taller buildings. This can be quite dangerous and can lead to story collapse.

Diaphragm Action

The diaphragm configuration is the shape and arrangement of horizontal resistance elements that transfer forces between vertical resistance elements. Diaphragms perform a crucial role in distributing forces to the vertical seismic resisting elements. The diaphragm acts as a horizontal beam and its edges act as flanges. Geometrical irregularities are analogous to such irregularities in other building elements, leading to torsion and stress concentration. The horizontal inertia forces generated by the ground motion at different locations of the floor must be transferred to the vertical elements such as walls. For this, the floor must act as a diaphragm. Cast-in-situ reinforced concrete or reinforced brick slabs are quite effective as diaphragms. However, other types of floors such as timber, if not properly connected together for seismic loading, may not provide for the diaphragm action.

Discontinuities in the diaphragm due to the presence of large cut outs hinder the ability of the diaphragm to transfer lateral forces to the walls. Diaphragms cannot be determined from building exteriors during rapid visual screening surveys and may be observed only if access to a building is possible. The same is true of cut outs in diaphragms. Considering the importance of proper diaphragm action in the seismic performance of buildings, a penalty modifier of -10 has been proposed in situations where absence of proper diaphragm action can be confirmed. No modifiers are proposed for situations where diaphragm action is either present or undeterminable through visual screening alone.

Soft/weak stories

A soft or weak storey is created when the lateral stiffness and/or strength of a storey is markedly more flexible than the floors above and below. This often occurs at the ground floor when it is left open for parking, for a shop front, or other reasons. Most of the deformation demand from the seismic event is concentrated at this level and results in large rotation demand in columns that has not been designed for ductility. Soft/weak storey collapses have been seen in many past earthquakes. It usually occurs in a building located along the side of a main street and has a less stiff and strong ground story, compared to that of the upper ones.

The ground stories which have level access from the street, are employed as a street side store or a commercial space whereas the upper stories are occupied by residences. These floors benefit from the additional stiffness and strength provided by many partition walls but the commercial space at the bottom is mostly left open between the frame members for customer circulation. Besides, the ground stories may have taller clearances and a different axis system, resulting in irregularity. The compound effect of all these negative features from the earthquake engineering perspective is identified as a soft story. Many buildings with soft stories were observed to collapse due to soft story in the past earthquakes all over the world.

Short Column Failure

A Short column failure is caused by its relatively high stiffness in comparison to other columns at that floor level. The transverse forces generated at a floor level are distributed in proportion to the member stiffness. Therefore, a short column will attract a greater proportion of the load and when compared to a more slender member, will have less ability to withstand the deflections that will occur over their height. Frames with partial infill lead to the formation of short columns which sustain heavy damage since they are not designed for the high shear forces due to shortened heights that will result from a strong earthquake.

Semi-in-filled frames, band windows at the semi-buried basements or mid-story beams around stairway shafts lead to the formation of short columns in concrete buildings. These captive columns usually sustain heavy damage during strong earthquakes since they are not originally designed to receive the high shear forces relevant to their shortened lengths. Short columns can be identified from outside because they are usually found along the exterior axes.

Frame Action

Load transfer means to support the loads acting on the building and to safely carry them down to the soil below. In a framed building, the load is transferred by 'Frame Action'. First the load is transferred from slabs to the beams, which is followed by the beams transferring them to columns immediately below them. These columns transfer the load to the lower columns. While a beam carries the load for that floor only, a column carries the load for all the floors above it. The lowermost columns transfers the load to the foundation, which, in turn, transfers it to the soil.

Falling Hazards

Presence of various non-structural components such as air conditioning units, parapets and advertisement hoardings can cause injury to pedestrians as well as to building occupants and the contents during an earthquake. Even though these may not have implications for the overall structural safety of the building, they can and do contribute to earthquake related losses, as is evident from the instances of chemical spills, breakage to building contents, misalignment of piping, etc.

Falling hazards include mechanical and electrical equipment, piping and ducting, unsecured masonry parapets and eccentrically placed water tanks on top of the buildings. A slab or a beam supported only on one side and projecting horizontally on the other side is called a 'Cantilever' slab or beam e.g. balconies, lofts and canopies. Figure 41 shows the locations of a falling hazards in a building.

Vertical Irregularities

Vertical building should also be vertically regular to increase the building safety during earthquakes. There should not be any discontinuation in the path of load transfer from top of the structure to the supporting foundation. For this purpose all columns and walls should run throughout the height of the structure. Any discontinuity in the load transfer can cause potential damage to the structure.

Open ground storey for car parking is one type of vertical irregularity. Sudden change in the stiffness causes the extreme stresses in the columns of ground storey to collapse the upper floors.

Setback and stepback in the buildings can also be considered to be vertical irregularity. Buildings with cantilever projection in the building on the upper floor or step back in the subsequent floors, are more vulnerable to earthquakes.

Apparent Quality

Quality of construction has a significant impact on the seismic performance of the building. Although it is difficult to judge the apparent quality of the building, certain observations can be made to assess the current condition of the building. These observations include seepage, corrosion of steel, spalling of concrete and structural cracks which developed in the building element. It can be assumed that buildings showing the above signs have used poorer quality of construction in comparison to the buildings that look better. The level of corrosion and concrete damage is also dependent on the age of the building.

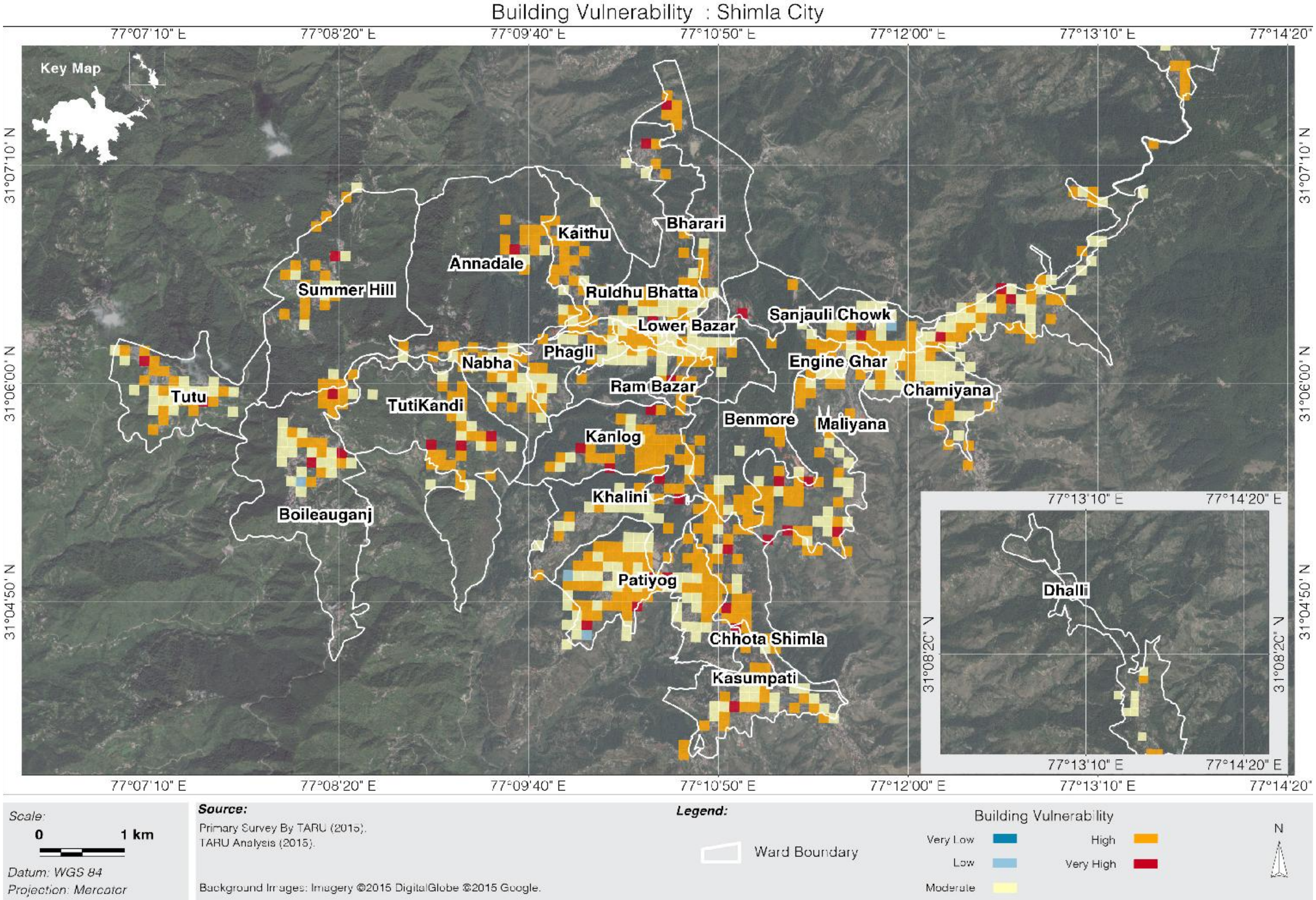
Wall Opening

Opening in the wall reduces its stiffness and in spite of their functional requirement in the building, their spacing and location affects the building's performance. Masonry walls are load bearing walls which needs to have good interlocking at the corners. Openings near the corner of the wall reduces the flow of forces from one wall to another and thus they need to be located away from the corners. Opening size should be kept as small as possible to avoid the reduction in the stiffness and load carrying capacity of the walls.

Horizontal band

In masonry buildings, it is mandatory to provide the horizontal bands in the buildings lying in the seismic zone IV and V to make them safe against earthquake. Horizontal bands of reinforced concrete should be provided at plinth, sill, lintel and roof level on all the walls. These bands help to keep the walls intact like a box structure and reduces the probability of out of the plane movement of the wall during earthquake shaking. Horizontal band reduces the unsupported height of the wall and thus improves their stability in weak direction.

In flat roof buildings, separate roof band is not required as flat roof acts as roof band. However, it must be provided for sloped roofing like gable roof, hip roof etc. In sloped roofing, other bands such as gable bands are also provided.The result of the RVS score is depicted in Map 20. The darker grids are the ones with highly vulnerable buildings and lighter shade indicates relatively low vulnerability.

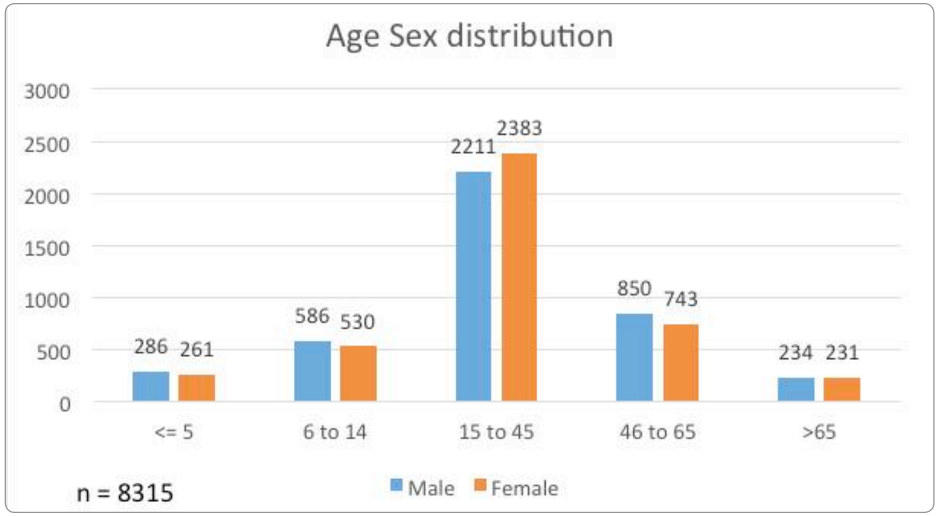


Map 20: Ward wise building vulnerability

3.1.2 Population Vulnerability

Population vulnerability is defined as the presence of vulnerable groups of the society and their geographical spread around the city. It can be defined as the intrinsic vulnerability of this population. Much of the population is present on more marginal locations of the city i.e- steeper slopes, creeping slopes, sinking zones, along the natural drainage network, etc. Based on the socioeconomic survey, vulnerability of the population is assessed.

A total of 8,354 people were interviewed amd 2001 households were covered as a part of the socioeconomic survey in the 25 wards. The average household size in these wards is 4.15.



Source : TARU Survey

Figure 27: Age Sex distribution

As is evident from Figure 27, out of the total of 8,315 people, 50.1% were male and 49.9% were female, with a majority of the population were in the age group of 15 to 45 years. Thus, it was inferred that majority of the population were in the working age group, as per the Census of India classification. As seen in Table 22, about 55% of the people were in the middle age cohort, which is a positive sign for any population, since the proportion of dependents is less.

Age group	No. of respondents	Percentage
<= 5	547	6.6
6 to 14	1,116	13.4
15 to 45	4,594	55.2
46 to 65	1,593	19.2
>65	465	5.6
Total	**8,315**	**100.0**

Source : TARU Survey

Table 22: Age wise break up

A majority of the population are in the age group of 15 to 45 years. Thus,a majority of the population are in the working age group. About 55% of the people were in the middle age cohort, which is a positive sign for any population, since the proportion of dependents is less.

Education Status

More literate a society, more aware a society. An aware member of a society will be updated on various government schemes and information that has been disseminated by various agencies, including the disaster management authority. Of the surveyed households, about 2.6% of the males and 6.75% of the females were not literate. Apart from this, other education cohorts doesnot not show much variation between both male and females. In the field of technical education, the enrolment of females was 3 % lesser that of the males. The literacy levels have been indicated in Table 23.

Highest class completed	Male		Female	
	No.	Percentage	No.	Percentage
Not literate	104	2.66	266	6.75
Literate, no formal schooling	46	1.18	58	1.47
Class 3 or less	295	7.54	290	7.36
Class 4-5	230	5.88	288	7.31
Class 6-9	485	12.39	465	11.81
Secondary	525	13.41	526	13.36
Class 11	81	2.07	83	2.11
Class 12	583	14.90	572	14.53
BA/BS/B.Com	952	24.32	804	20.42
MA	390	9.96	474	12.04
M Phil	40	1.02	42	1.07
Technical	183	4.68	70	1.78
Total	**3,914**	**100**	**3,938**	**100**

Source : TARU Survey

Table 23: Literacy levels

Income Classification

The income disparity is very high in Shimla, with the income ranging from below Rs 100 to more than 1 crore (10 million) a month. Income was recoded into class intervals of 5000, leaving out the outliers. On comparing the educational status and the income, it was determined that majority of the population were salaried or regular wage employees. Shimla being the state capital and the district head quarter, many people are also engaged in the government services.

Given the time during which the survey was conducted, many of the respondents were only the housewives who stayed at home. So highest share of work is depicted as 'house wife'. Second predominant work is the regular waged/salaried. This shows the economic stability of the households surveyed. The households with irregular income pattern are more vulnerable compared to the others.

Type of employment	No. of employees	Percent
Self employed	741	8.9
Employer	265	3.2
Helper in HH enterprise	64	.8
Regular salaried/wage employee	1457	17.4
Casual wage labour	106	1.3
Piece rate worker	55	.7
Apprentice	87	1.0
House Wife	1897	22.7
Total	**4672**	**55.9**

Source : TARU Survey

Table 24: Distribution of employment

Dependency ratio

About 42% of the population are not working and hence has no earning. Rest of the family members of the surveyed household were earning on the basis of their employment types.

When education and income are correlated, there is a strong positive correlation between higher education and higher incomes. This illustrates that the share of traditional economic activities are relatively lesser in the overall work pattern.

Income classes in INR	No. of people	Percentage
Not earning	1,997	42.7
Up to 5,000	321	6.9
10,000	539	11.5
15,000	353	7.6
20,000	303	6.5
25,000	222	4.8
More than 30,000	937	20.1

Source : TARU Survey

Table 25: Earners and Dependents

Earnings of different employees are depicted in the table above. There are two inferences that can be made from this table – 1, ie- firstly, majority of the people have stopped their education either at secondary or class 12 or graduation and post-graduation. Secondly, higher income are seen among the graduates and post-graduates, as usual. Majority of the family members have finished graduation (BA/BS/BCom) followed by class 12 and secondary education (Table 26).

There are about 100 different government buildings in the city of Shimla (Table 27). They range from Rajbhavan, office of the Divisional Commissioner's, Railway Station, PWD office, water works, post office, police stations, electricity offices, directorates of various departments, various state government, departments, state pollution control board and NABARD, to the Government press. All these buildings were analysed for structural integrity and stability. RVS was derived based on various parameters, both structural as well as non-structural.

	Not literate	Literate, no formal schooling	Class 3 or less	Class 4-5	Class 6-9	Secondary	Class 11	Class 12	BA/BS/BCom	MA	M Phil	Technical	Total
No Income	259	88	570	409	740	645	141	727	934	419	30	152	5114
5000	32	4	4	28	63	69	5	53	46	23	1	6	334
10000	44	6	5	35	66	90	5	120	121	45	2	8	547
15000	22	2	3	17	41	58	3	60	110	35	4	11	366
20000	7	2	1	19	22	55	3	46	93	50	5	10	313
25000	2	2	0	3	8	46	2	36	85	48	4	7	243
30000	4	0	2	7	10	88	5	113	367	244	36	59	935
Total	370	104	585	518	950	1051	164	1155	1756	864	82	253	7852

Source : TARU Survey

Table 26: Income Vs Education qualification

		Types of employment								
Income-INR		Self employed	Employer	Helper in HH enterprise	Regular salaried/ wage employee	Casual wage labour	Piece rate worker	Apprentice	House wife	Total
No Income	No	20	5	19	17	1	5	59	1871	1997
	%	1	0	1	1	0	0	3	94	100
5000	No	110	50	6	76	41	28	4	6	321
	%	34	16	2	24	13	9	1	2	100
10000	No	183	70	20	203	36	13	3	11	539
	%	34	13	4	38	7	2	1	2	100
15000	No	126	39	5	151	21	4	4	3	353
	%	36	11	1	43	6	1	1	1	100
20000	No	78	26	4	180	5	1	8	1	303
	%	26	9	1	59	2	0	3	0	100
25000	No	50	19	5	138	2	1	5	2	222
	%	23	9	2	62	1	0	2	1	100
30000	No	174	56	5	692	0	3	4	3	937
	%	19	6	1	74	0	0	0	0	100
	No	741	265	64	1457	106	55	87	1897	4672
	%	16	6	1	31	2	1	2	41	100

Source : TARU Survey

Table 27: Share of different employment type and income variation

3.2 Social Vulnerability

Social vulnerability is intrinsic vulnerability of a household and is usually attributed by the social background of the household as well as the means of economic sustenance. Table 28 shows the list of parameters used in identification of social vulnerability. These parameters were collected through socioeconomic survey and analysed for the vulnerability index. The results are shown in the series of maps below.In Map 21, the households which do not have an access to their house from the motorable roads are shown in red colour, which in turn enhances people's inability to escape in case of any eventuality. So these households need to be considered while making any preparedness plans of emergency management plans. Some such locations are- Kanlog, Maliyana, Annadale, Kaithu and Boileauganj.

From Table 29, we can see that the wards like Lower bazar, Ruldhu Bhatta, Kaithu, Chamiyana, Phagli have more than 80% of the households staying away from the motorable road, who has to use intricate network of staircases and narrow walkways to reach their houses. On the other hand, Ram Bazar, Boileauganj, Sanjauli chowk, Dhalli, Kasumpti, Chhota Shimla and Pateog have majority of the households closer to the main motorable road. In the Table 28, the red cells in column 5, shows the areas where special efforts need to be made in order to make any evacuation plan or emergency management plan. This will also make the logistics of the relief supplies more difficult in the aftermath of an emergency. Hence, there is a need for the corporation to involve the citizens of each ward in the preparedness drills, to be held henceforth.

Map 28 shows the distance of the nearest fire station to the households. In the city, there are 3 fire stations, as has been shown in the figure. In context of the proximity to the fire station, red grids refers to the region where the households are around 10-12 kms away from the nearest fire station. Considering the average traffic speed in the the city, it will be very difficult for the fire administration to serve effectively on time. Map 25 indicates the service time taken for the fire services to reach the households. As has been shown in Map 28 Access to Emergency services - Fire Stations (by duration), Pateog, Maliyana, parts of Bharari and Dhalli areas are not well served by the fire stations. Narrow roads

Concept	Description	Increase (+) or decrease(-) social vulnerability.
Socioeconomic status (income, political power, prestige)	Wealth enables communities to absorb and recover from losses more quickly due to insurance, social safety nets and entitlement programs.	High status (-) Low income or status (+)
Gender	Women can have more difficult time during recovery compared to men because of the traditional lifestyles and physical strength.	Gender (+)
Ethnicity	Imposed language and cultural barriers that effect access to post disaster funding and residential location in high hazard areas.	SC/ST/OBC (+) General (-)
Age	Extremes of the age spectrum affect the movement out of harm's way.	Elderly (+) Children (+)
Employment	The potential loss of employment following a disaster exacerbates the number of unemployed workers in a community, contributing to a slower recovery from the disaster.	Employment loss (+)
Residential Property	The value, quality and density of residential construction affects potential losses	
Infrastructure and lifelines	Loss of sewers, bridges, water, communications, and transportation infrastructure compounds potential disaster losses.	Extensive infrastructure (+)
Tenants	They often lack access to information about financial aid during recovery	Renters(+)
Occupation (permanency of it)	Depending upon the type of occupation people will be vulnerable towards hazard	Professional (-) Clerical or labourer (+) Service sector (+)
Family structure	Families with large number of dependents have limited finance to outsource care for dependents.	Large families (+) Single parent household (+)
Education	Lower education constrains the ability to understand warning information and access to recovery information.	Less educated (+) Highly educated (-)

Table 28: Determinants of Social Vulnerability

Ward No	On the main road		Interior from the road		Total	Ward name
	No.	Percentage	No.	Percentage		
1	17	32.7	35	67.3	52	Bharari
2	9	11.1	72	88.9	81	Ruldhu Bhatta
3	10	15.9	53	84.1	63	Kaithu
4	20	39.2	31	60.8	51	Annadale
5	34	35.4	62	64.6	96	Summer Hill
6	35	25.9	100	74.1	135	Totu
7	61	48.0	66	52.0	127	Boileauganj
8	9	25.0	27	75.0	36	Tutikandi-Badai
9	17	33.3	34	66.7	51	Nabha
10	6	12.2	43	87.8	49	Phagli
11	16	34.0	31	66.0	47	Krishna Nagar
12	9	52.9	8	47.1	17	Ram Bazar,Ganj
13	2	10.0	18	90.0	20	Lower Bazar
14	16	43.2	21	56.8	37	Jakhu
15	6	37.5	10	62.5	16	Benmore
16	14	30.4	32	69.6	46	Engine Ghar
17	36	52.9	32	47.1	68	Sanjauli Chowk
18	47	48.5	50	51.5	97	Dhalli
19	31	18.5	137	81.5	168	Chamyana
20	33	30.8	74	69.2	107	Maliyana
21	65	41.7	91	58.3	156	Kasumpti
22	36	44.4	45	55.6	81	Chhota Shimla
23	104	55.9	82	44.1	186	Pateog
24	44	37.3	74	62.7	118	Khalini
25	32	33.7	63	66.3	95	Kanlog

Table 29: Ward wise percentage of households with access from motorable road

and insufficient turning radius, prevents the fire service vehicles from accessing all the roads. The selected wider roads will take more time to reach these areas, making each of these wards more vulnerable.

3.2.1 Access to Services

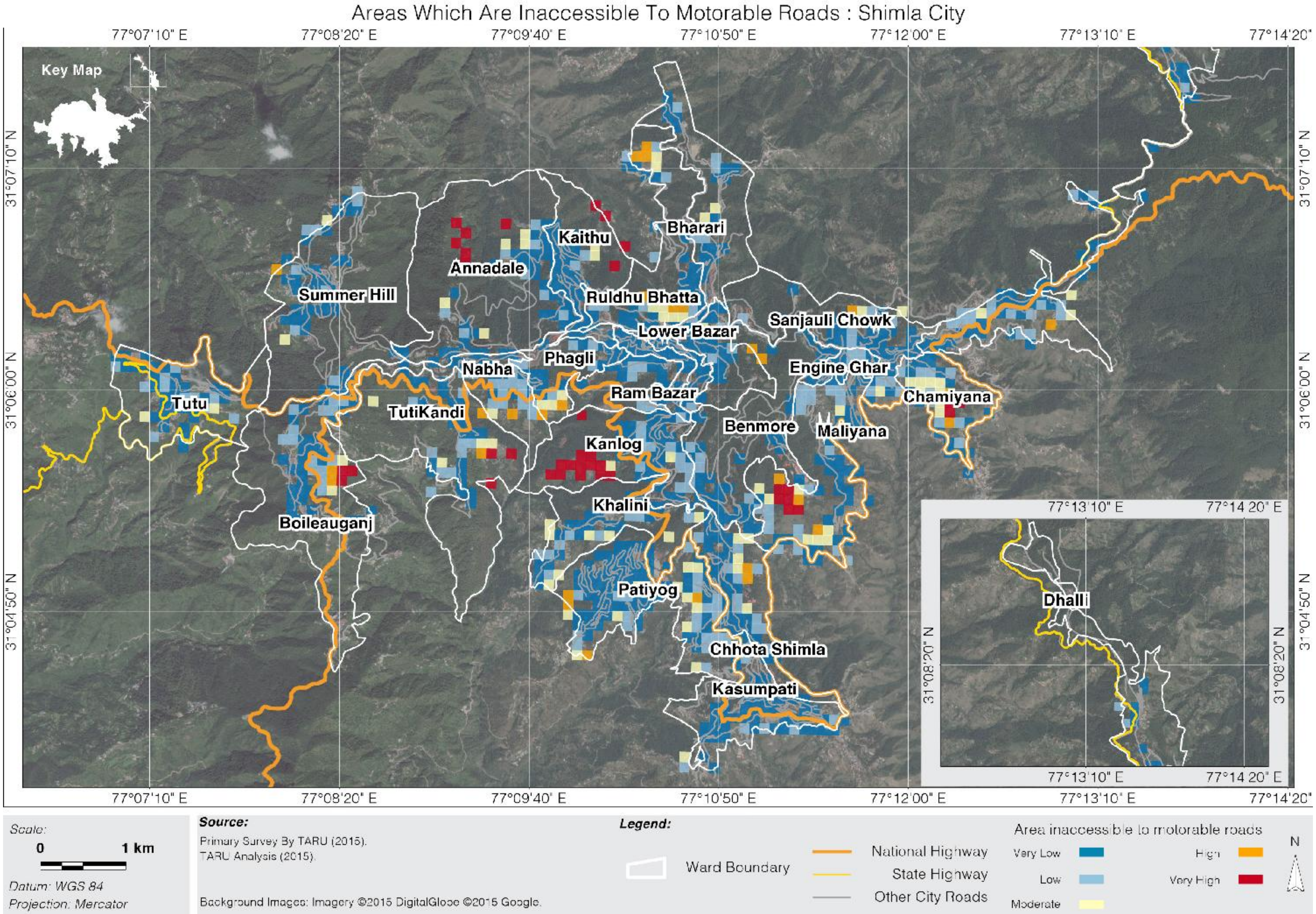
Water Supply and Sanitation

Water supply in this city is very erratic and comes from many sources. Based on the parameters, source for drinking, who fetches water, time required in fetching, means of main storage, storage coverage, availability of water in hours per day and adequacy of water pressure, an index is derived and the same has been mapped in Map 22. The bright red grids shows the areas where the households having difficulty in accessing water has been indicated.

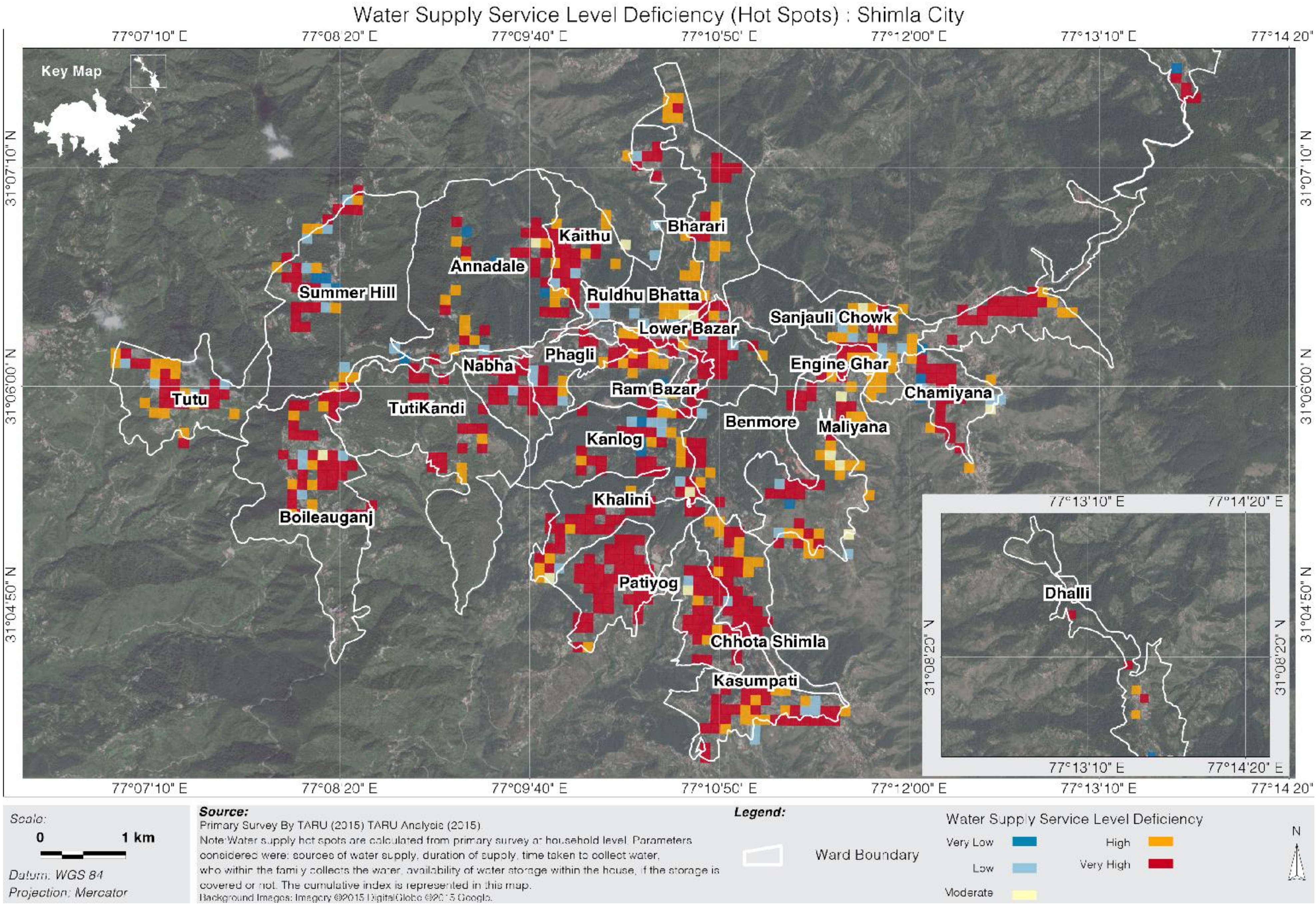
In terms of sanitation, there are areas where open defecation (OD) is prevalent even today. The red grids in Map 23, showing wards Totu, Kanlog, Sanjauli Chowk, Chhota Shimla and Kasumpti, are the places where open defecation has been noticed due to the lack of proper sanitation facilities. Light blue grids are the areas where the toilets are connected to open gutters and the overall condition is relatively better. In places shown in ochre, the toilets are not connected to any sewer system. This information can be used in order to identify the areas where chances of hygiene related diseases may occur, so that new sanitation schemes can be undertaken.

It is also observed that there are some sections of the population with various diseases in these wards shown in Map 24. Almost all the wards have the population which may need special attention even in the absence of emergency. These are the households which have reported various diseases that have taken place in last 2 years. These diseases range from lifestyle diseases, like obesity, blood pressure, etc. to malaria, typhoid, etc. Hotspots shown in the map indicates the households with recent history of diseases. In case of any emergency these households (the data need to be updated regularly in order to maintain a latest data on the diseases and the spatial spread of them) will need specially attention.

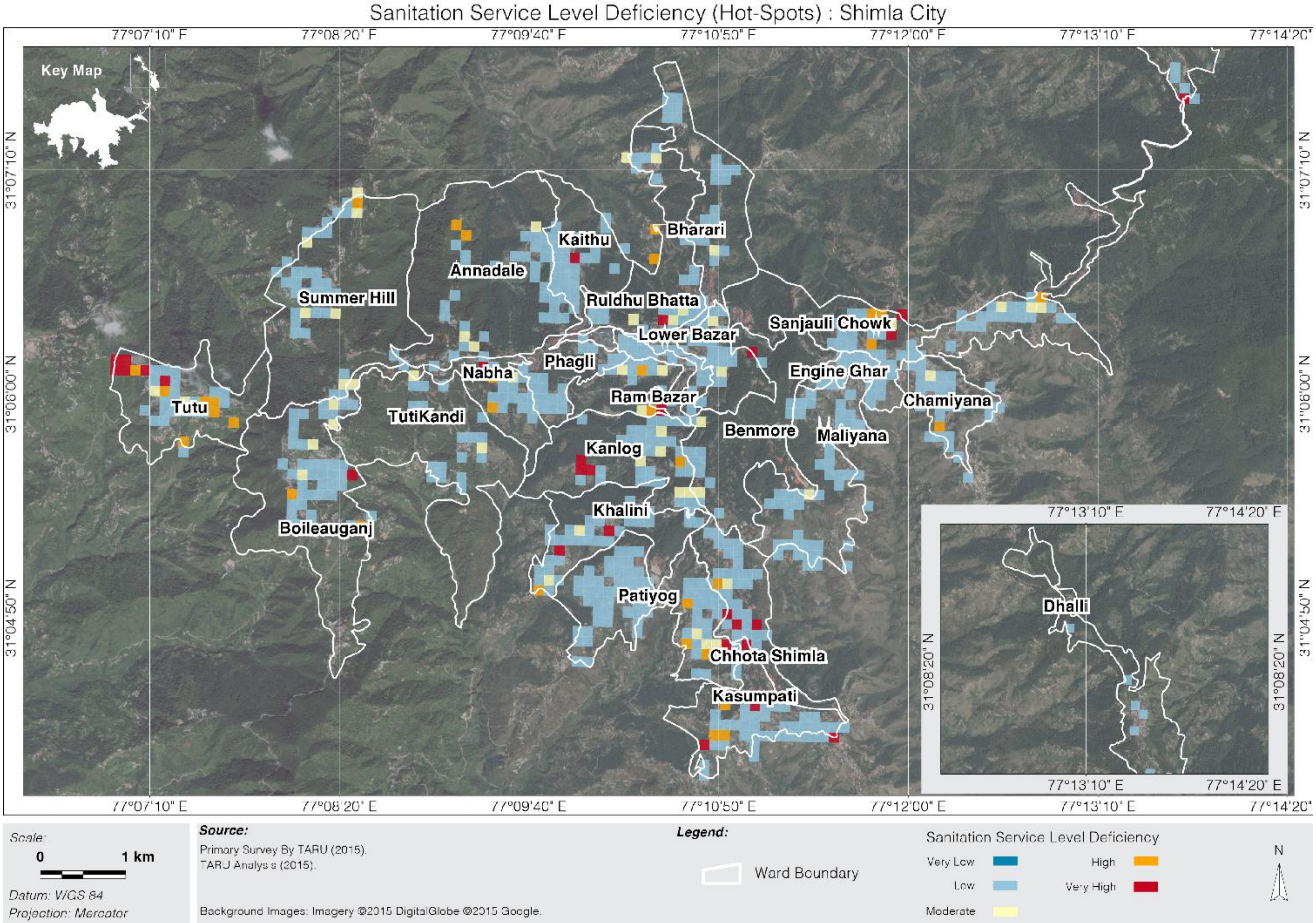
The population which is shown on the higher side in terms of various social, economic, population or service related vulnerability, are those that are already 'intrinsically vulnerable'. When coupled with the results of hazards, the shock will be irrecoverable. Thus identifying the vulnerable groups and mapping them will help in reducing the overall risk. The next chapter assesses the risk caused by the hazards and vulnerabilities discussed so far.



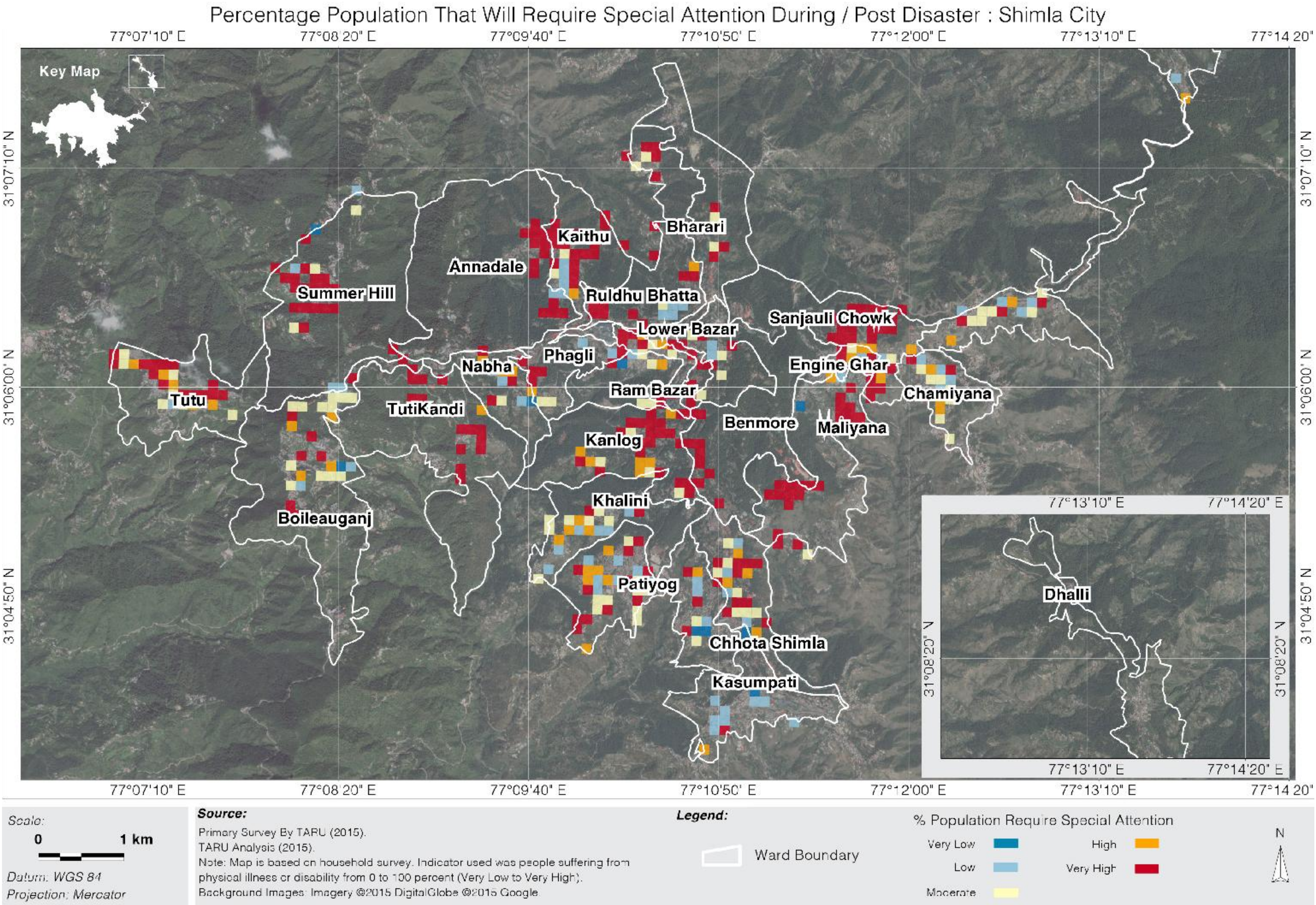
Map 21: Road access hotspots for household



Map 22: Water supply hotspots within the city



Map 23: City level Sanitation hotspots



Map 24: Ward wise, Population that need special attention

Access to Health Facilities

All the sampled households were considered for assessing the distance and time taken for accessing the reach of health facilities. A computer based algorithm was run with all the sampled households (3,126) with a nearest hospital (one of the 7 government hospotals). The government hospitals considered in the simulation are:

No	Particulars of Health Institutions	Beds (Sanctioned)	Beds (In position)
1	DDU Zonal Hospital, Shimla	300	150
2	Indira Gandhi Hospital, Shimla	661	800*
3	Kamla Nehru Hospital, Shimla	114	134
4	Rippon Hospital	NA	NA
5	Military Hospital	NA	NA
6	Regional Cancer Hospital	NA	NA
7	Govt. Dental Hospital	NA	NA

* IGMC website accessed on 1 Feb 2016

Table 30: Particulars of Health Institutions in Shimla

Access to Hospitals

Access to hospitals is another critical measure for understanding the vulnerability of the households. Below table shows how many households are how much distance from the nearest hospital. As shown in the Table 31, about 65% of the houses are either 5km or more from the nearest hospital.

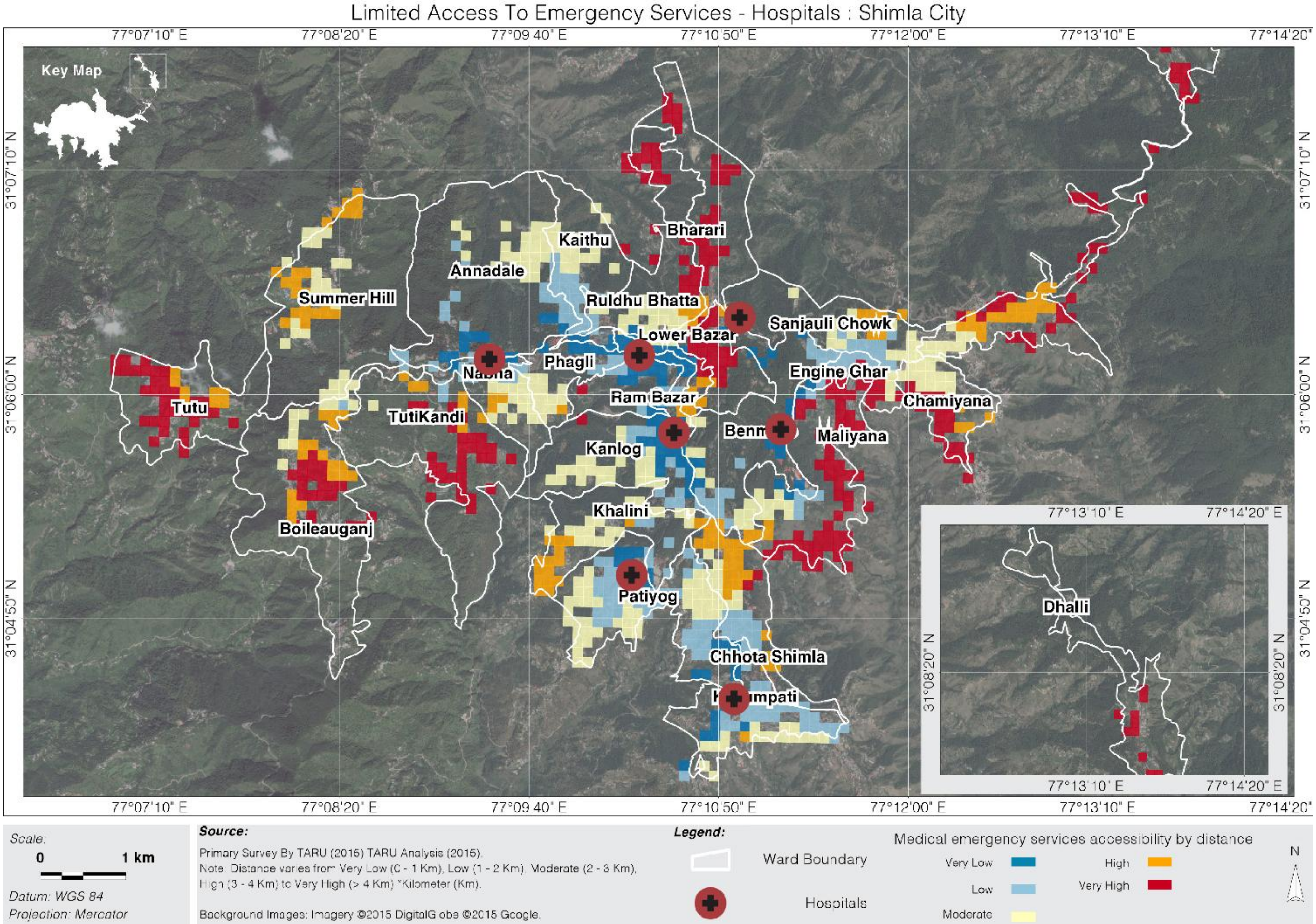
About 8% of the households have to travel more than 20min in order to reach a hospital. Considering the traffic conditions, and traffic jams within the city, the cost payable by these households to acces health facilities is much pricier. As Table 32 shows, majority households (56%) are within a distance of 10min. travel. As mentioned earlier, the distance is only notional and based on the real experience, the roads of Shimla cannot facilitate such time in reaching from one point to another. tioned earlier, the distance is only notional and based on the real experience, the roads of Shimla cannot facilitate such time in reaching from one point to another.

Distance from Hospital	No. of households	Percent
500	131	4.2
1,000	263	8.4
2,500	723	23.1
5,000	1,507	48.2
7,500	339	10.8
10,000	140	4.5
15,000	23	0.7
Total	**3,126**	**100.0**

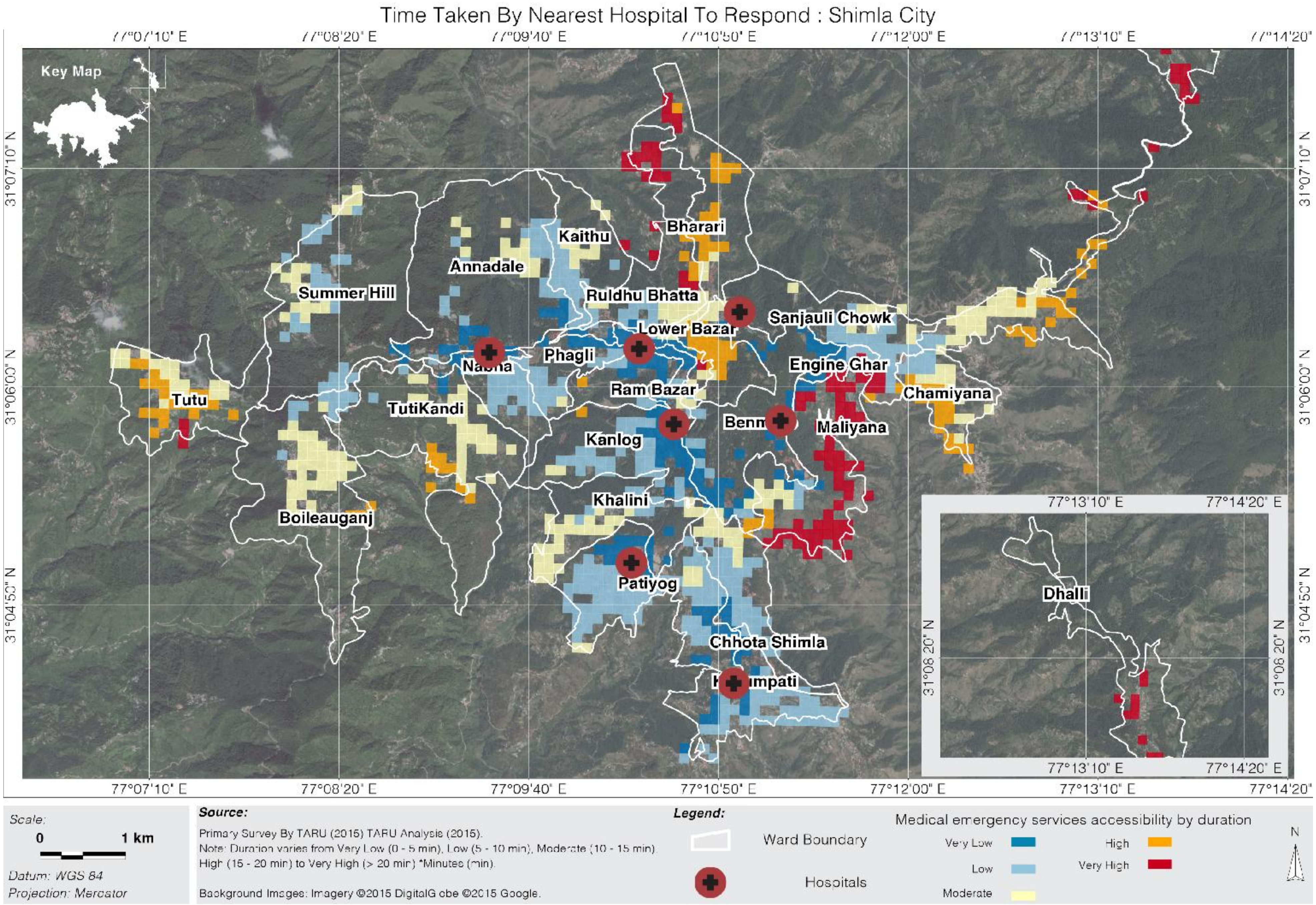
Table 31: Distance from nearest hospital to houses

Time taken to reach Hospital	Frequency	Percent
5	625	20.0
10	1,134	36.3
15	708	22.6
20	396	12.7
25	160	5.1
30	67	2.1
60	36	1.2
Total	**3126**	**100.0**

Table 32: Average time taken to reach the hospital from houses



Map 25: Access to Emergency services - Govt. Hospitals (by distance)



Map 26: Access to Emergency services - Govt. Hospitals (by duration)

Access to Fire Service

There are three fire stations within the city boundary. However the access to individual houses is very narrow and many of the times not accessable at all. In understanding the accessibility of the services, two components are important. Distance from the service and time taken to access the service. A GIS based analysis was carried out using GoogleMaps to calculate the distance and the time taken to reach these services. For fire services, 3 services within the city limits are considered while for the hospitals, 7 government run hospitals area considered. The private hospitals are not taken into consideration for this analysis. There are private hospitals within the city in every nook and corner. If those hospitals are considered, the distance and duration to reach them will be reduced considerabley. However, considering the cost of accessing their services, those services are deliberately excluded from this analysis. Distance to the nearest fire service from the households is explained below.

Distance from fire service in meters	No. of households	Percent
500	185	5.9
1000	152	4.9
2500	378	12.1
5000	1701	54.4
7500	523	16.7
10000	138	4.4
15000	49	1.6
Total	**3126**	**100.0**

Table 33: Distance from nearest fire station to households

As shown in Table 33, about 55% of the houses are at a distance of 5km from the nearest fire station. Considering the traffic conditions of Shimla city, travelling the 5km can take more than 20min, which is crucial for any building.

As per the above Table 34, majority (73.5%) of houses are within the distance of 10 to 20min. in any fire accident, the most critical time is forst 20min. so if the fire services can reach the households within 20min, much of the damage can be minimized. However, based on the density of the houses and the material used to construction, this time may vary.

Time taken in minutes	No. of households	Percent
0	2	0.1
5	403	12.9
10	942	30.1
15	851	27.2
20	504	16.1
25	282	9.0
30	99	3.2
60	43	1.4
Total	**3126**	**100.0**

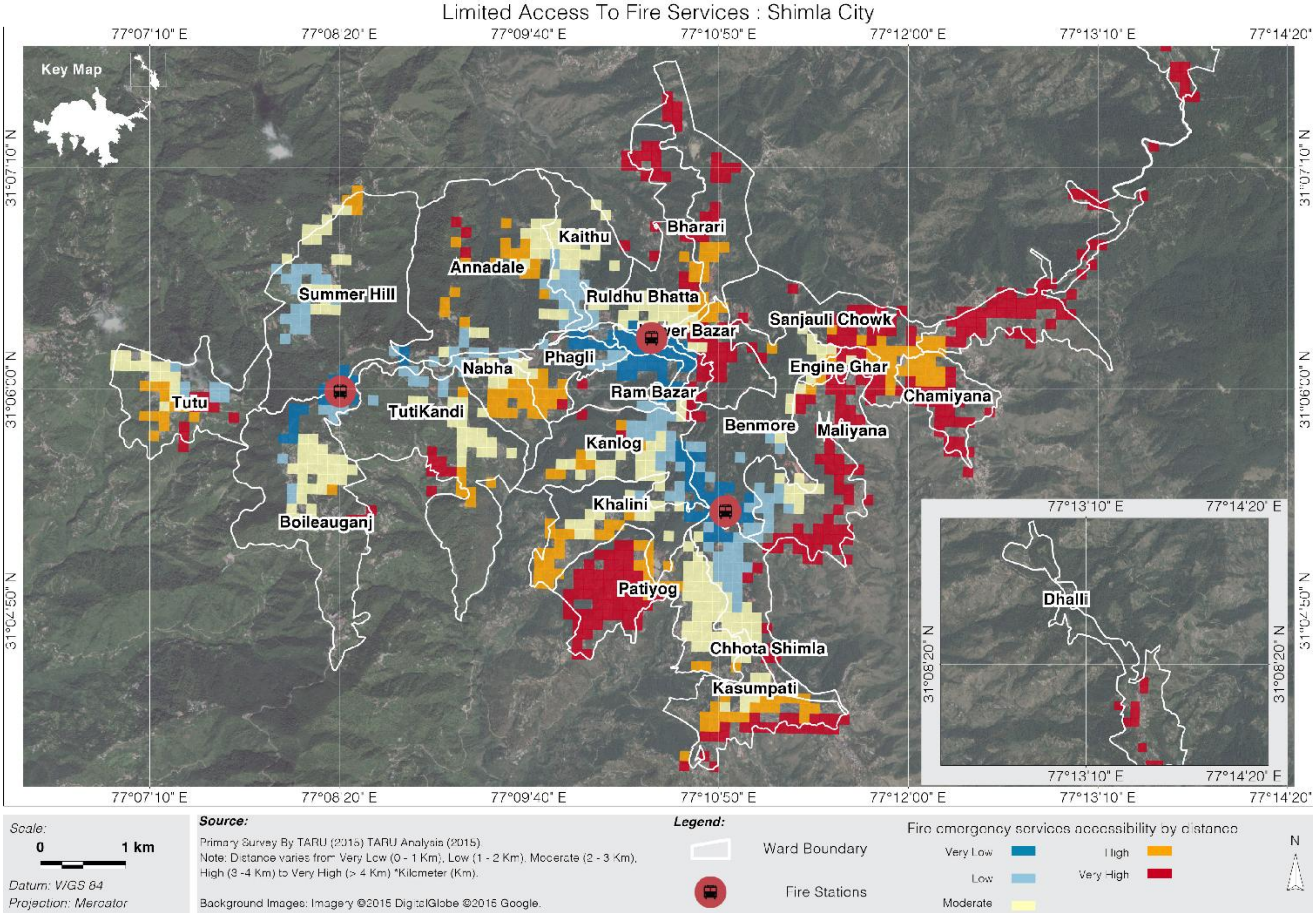
Table 34: Time taken for Fire service to reach the houses

Access to the Main Road

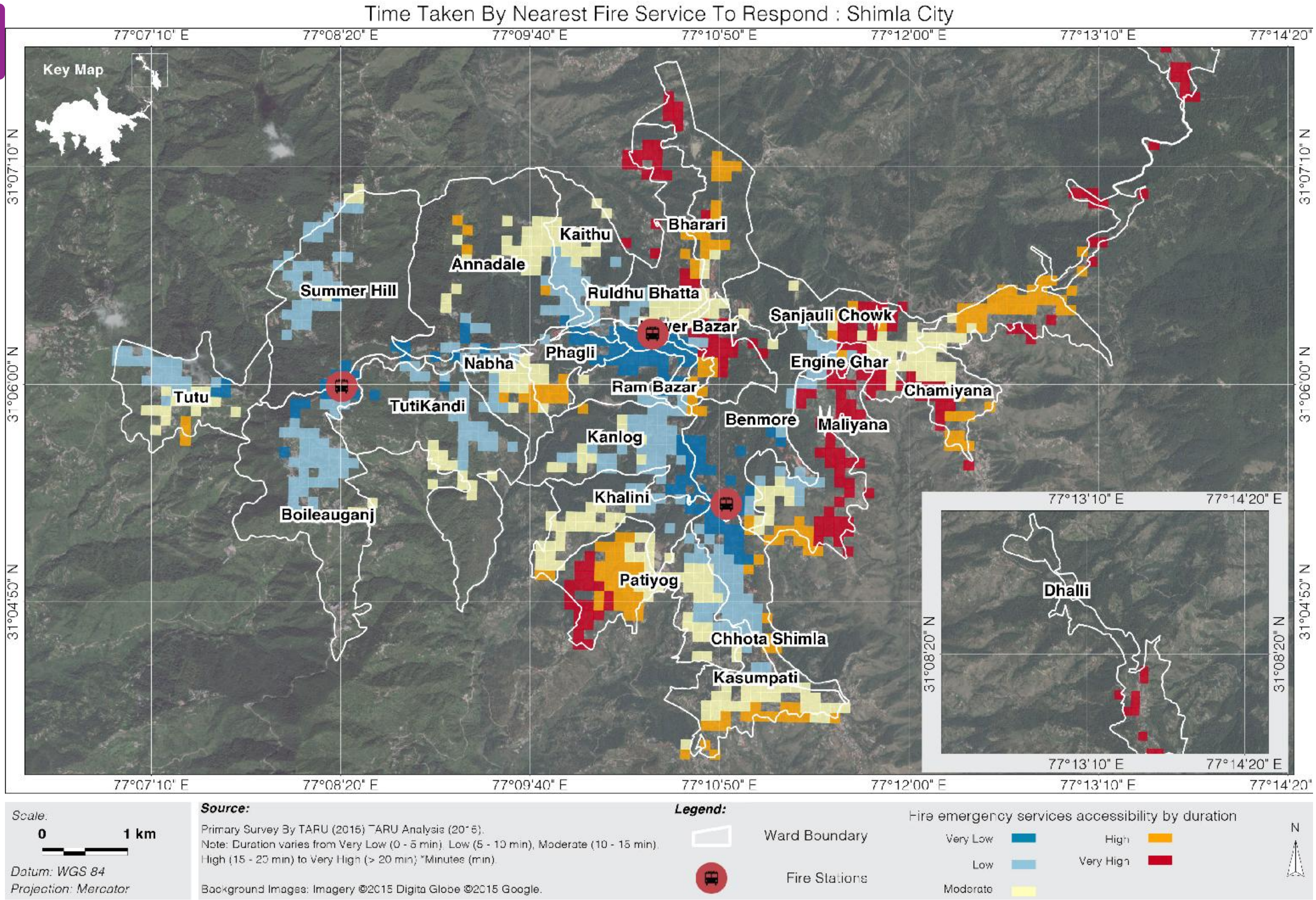
Based on the type of the access roads, households are assessed to the distance to the nearest motorable road. This is important in order to understand their evacuation time in case of a disaster. So as per our analysis, as shown in Table 35, about 6% of the households are located at a distance more than 500mt from the main access road. Special provisions need to be made for the evacuation of the households.

Distance from Access road	Frequency	Percent
50	2150	68.8
100	471	15.1
200	271	8.7
300	73	2.3
400	46	1.5
500	48	1.5
800	50	1.6
1200	17	.5
Total	**3126**	**100.0**

Table 35: Average distance to main access road from houses



Map 27: Access to Emergency services - Fire Stations (by distance)



Map 28: Access to Emergency services - Fire Stations (by duration)

3.3 Economic Vulnerability Assessment

Economic vulnerability of a country/ region/ city can be defined as the potential or capability of exogenous shocks faced by the society, to hamper its development. There are two sources of vulnerability - first is external which is mainly related to balance of trade or instability in the international market and second is vulnerability caused by natural disasters. In this study, we will focus on the vulnerability caused by the identified hazards and risks.

Economic vulnerability is of two types- micro-economic vulnerability, which is concerned with the well-being of individual households; and macro-economic vulnerability which is concerned with the overall economic growth. This section focuses on analysing and quantifying the impact of historical and probable natural disasters. It analyses the direct and indirect losses including probable maximum and average losses arising from damages caused by natural hazards of probable severity and frequency. Apart from identifying and assessing the losses, measures to be taken in order to minimise the shocks of such hazards has also been highlighted.

3.3.1 Approach and Methodology

Quantification of possible macro and micro impact has been carried out in various stages.

Stage I – Economic Profile of Himachal Pradesh

Economic profile of the state was prepared to have a clear understanding of the regional economy. This section covers the following:

- Position of the state in national economy
- Growth of Gross State Domestic Product (GSDP)
- Contribution of various sectors to the economy

Stage II – Economic Profile of Shimla

This focuses on the economic profile of the city, which covers:

- Estimation of city product through District Domestic Product (DDP
- Per capita income of the city
- Profile of various sectors significantly contributing to the city economy
- Future projections based on historical data
- Ward-wise location of residential and commercial properties

Stage III – Economic Vulnerability Projections

Based on the output of multi hazard vulnerability risk assessment, major economic centres that are falling under the hazard zones has been identified. Preparation of the inventory of economic activities located in high and low risk area, has been followed by quantifiable macro and micro impact projections, including:

- Short Term Direct Loss
  - Impact on livelihood both at city and regional level
  - Impact on housing/real estate both on residential and commercial
  - Impact on various commercial sectors

- Long Term Direct Loss
  - Change in GSDP
  - Change in city product

Stage IV – Capital Investment Plan

Based on proposed mitigation strategies a capital investment plan has been prepared for the city of Shimla. Investment plan covers phasing of various mitigation measures and capital required for each activity.

Stage V – Cost Benefit Analysis

Detailed economic analysis was carried out covering quantifiable economic benefits and costs required for implementation of various proposed mitigation measures. This analysis calculates EIRR (Economic Internal Rate of Return) and ENPV (Economic Net Present Value). Benefit cost ratio shows the future benefits of mitigation measures.

Economic Vulnerability Assessment

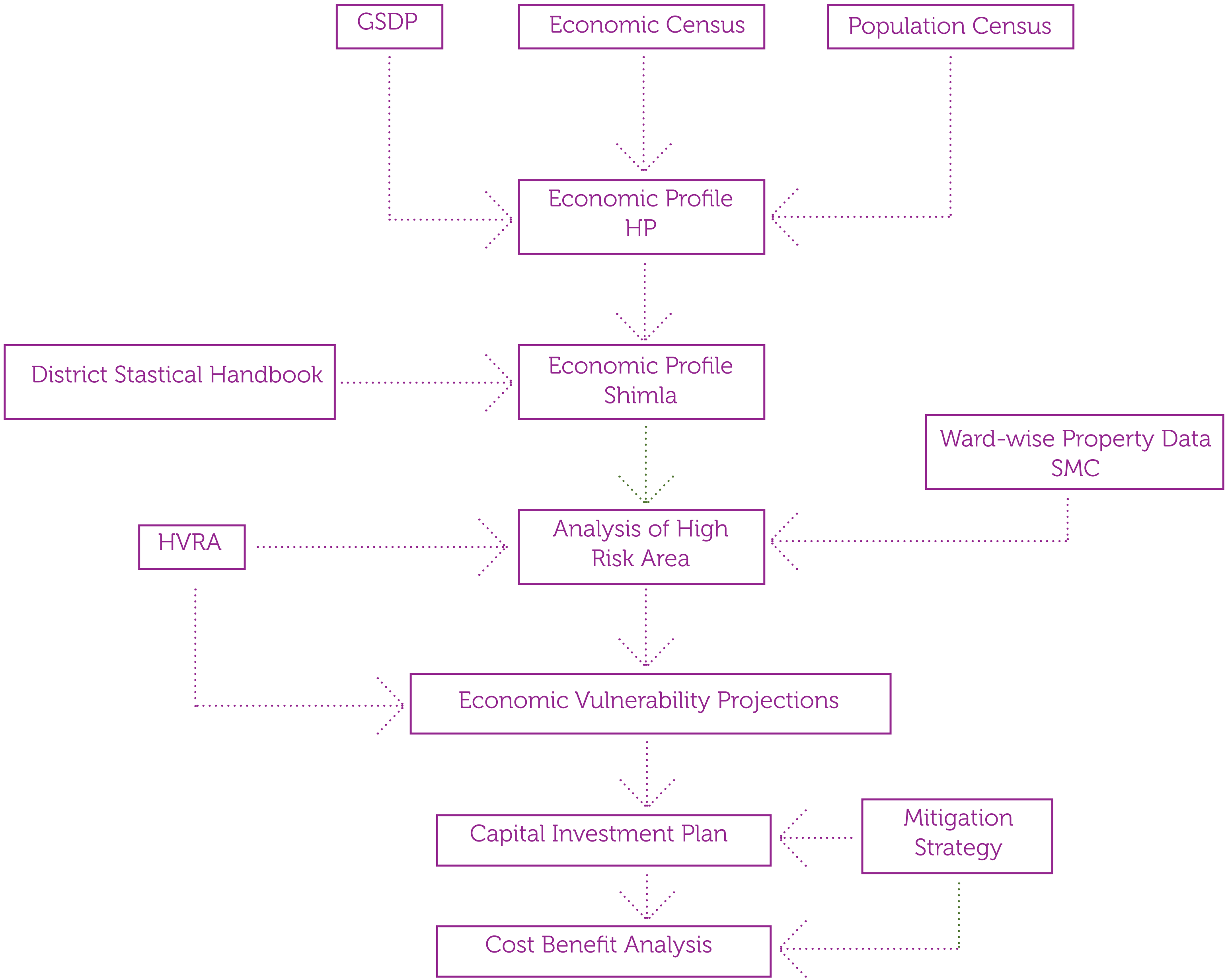


Figure 28: Economic Vulnerability Assessment

3.3.2 Economic Profile – Himachal Pradesh

Himachal Pradesh is one of the fastest-growing states in India. The gross state domestic product (GSDP) grew at a compound annual growth rate (CAGR) of 7.68 percent between 2004-05 and 2014-15. State's per capita SGDP is estimated to be US$ 2,008.5 during 2014-15 as compared to the national per capita GDP of US$ 1,389.61. The key economic indicators have been stated in Table 36.

No.	Indicators	2004-05	2014-15 (A)	CAGR
	GSDP (in Rs. Lakhs)			
1	Current Prices	2407658	9558671	14.78%
	Constant Prices	2407658	5047535	7.68%
	NSDP (in Rs. Lakhs)			
2	Current Prices	2118940	7464542	13.41%
	Constant Prices	2118940	4076346	6.76%
	Per Capita Income (Rs)			
3	Current Prices	33348	104953	12.14%
	Constant Prices	33348	57309	5.56%

Source : Directorate of Economics and Statistics, H.P.

Table 36: Key Economic indicators – Himachal Pradesh

The state gross domestic product (SGDP) at factor cost at constant (2004-05) prices in 2014-15 is estimated at 5047535 lakhs as against 4725476 lakhs in 2013-14 registering a growth of 6.5 percent during the year as against the growth rate of 6.2 percent during the previous year. At current prices, the SGDP is estimated at 9558671 lakhs as against 8258534 lakhs in 2013-14 showing an increase of 15.7 percent during the year. The per capita income at current prices witnessed an increase of 12.14 percent as it increased to 104943 in 2014-15 from 33348 in 2004-05.

The economic growth in the state is predominantly governed by agriculture and its allied activities did not show much fluctuations during the nineties as the growth rate remained more or less stable. This is evident from Table 35. In constant prices, agriculture and allied sector grew at the rate of 5.7 percent from 2004-05 to 2014-15, which is at par with the national level. The economy has shown a shift from agriculture sector to industries and services as the percentage contribution of agriculture and allied sectors in total state domestic product has declined from 26 percent in 2004-05 to 17 percent in 2014-15.

The share of industries and services sectors respectively has increased from 38 and 36 percent in 2004-05 to 39 and 44 percent in 2014-15. Average annual growth of secondary sector and tertiary sector from 2004-05 to 2014-15 was 7.8 and 9.75 percent. Contribution of manufacturing sector has increased from 11.51 percent in 2004-05 to 18 percent in 2014-15 (Figure 29).

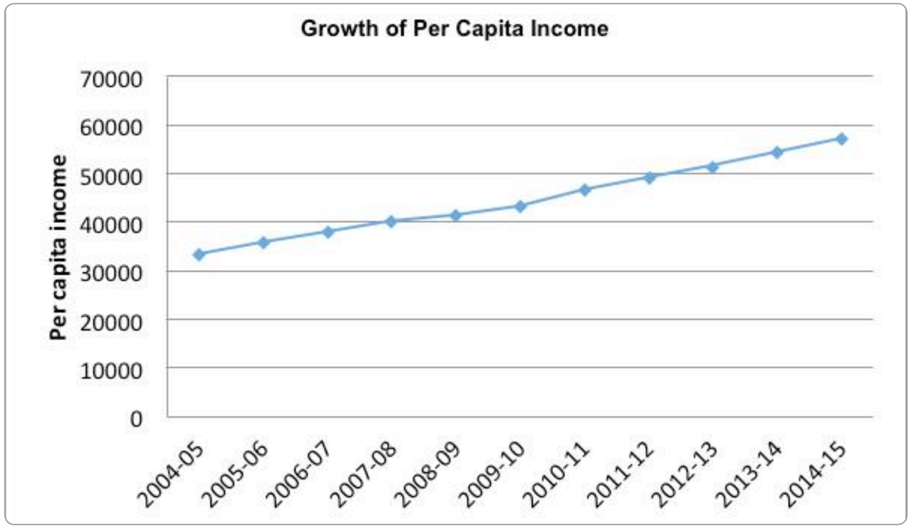
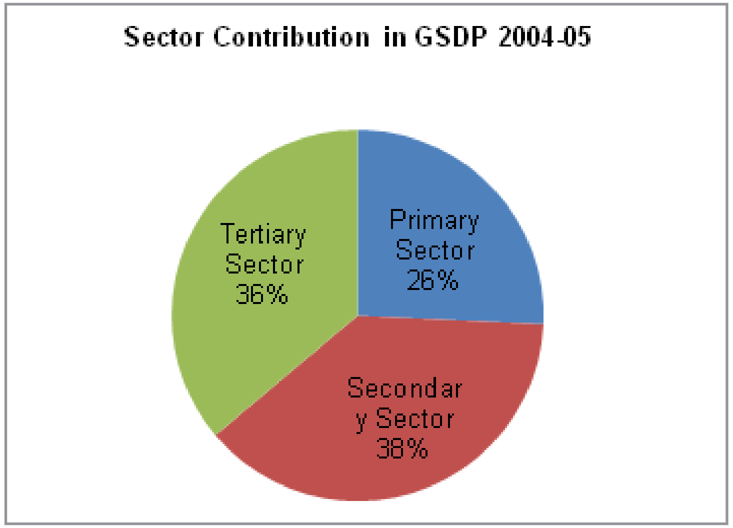


Figure 29: Growth of Per Capita Income

The declining share of agriculture sector do not, however, affect the importance of this sector in the state economy as the state economic growth still is being determined by the trend in agriculture and horticulture production. It is the major contributor to the total domestic product and has overall impact on other sectors via input linkages, employment and trade etc. Due to the lack of irrigation facilities the agricultural production to a large extent still depends on timely rainfall and weather conditions. High priority has been accorded to this sector by the govenment.



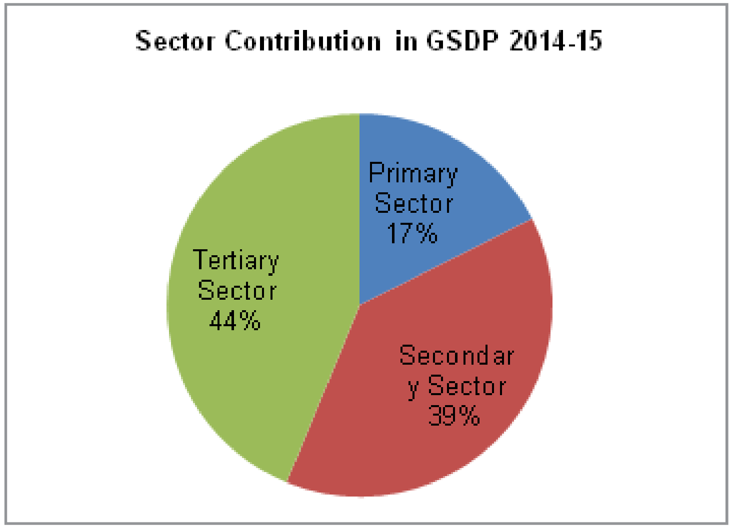


Figure 30: Comparison Sector Contribution in GSDP

The rich natural resources of the state are favourably suited for investments in major sectors such as procurement of agricultural produce, hydroelectric power, cement and tourism. Himachal Pradesh has made significant achievements in the field of industrialisation in the past few years. As of March 2015, there were 502 medium and large-scale industries and about 39,927 small-scale industries; with a total investment of around US$ 3 billion, in the state.

In an effort to provide infrastructural support to the entrepreneurs, the Himachal Pradesh government has developed 41 industrial areas and 15 industrial estates. Solan, Sirmour, Kangra and Una districts were the leading states in terms of investments attracted.
The following are some of the major initiatives taken by the government to promote Himachal Pradesh as an investment destination:

- Himachal Pradesh has made significant achievements in the field of industrialisation in the past few years.
- The Department of Environment, Science and Technology (DEST), Government of Himachal Pradesh, proposes to develop a biotechnology park (BTP) spread over an area of about 35 acres at village Aduwal in Solan under public-private partnership (PPP) model in the state. The park would have a Biotechnology Incubation Centre and a Biotechnology Industrial Cluster. As of May 2015, the park is already in process of being set up.
- Government has signed MoUs for the establishment of units with major cement players like Harish Cement (Grasim) at Sundernagar (Mandi district), India Cements Limited at Gumma-Rohaha (Shimla) and Lafarge India Limited at Alsindi (Mandi).
- State government has approved a new project on management of horticultural crops in the state. World Bank has approved a funding of US$ 166.7 million for this project.

3.3.3 Economic Profile - Shimla

Shimla being the state and administrative capital of Himachal Pradesh, majority of economic activities are concentrated in Shimla. Natural resources play a key role in economic survival of the town and hinterland, as tourism and agriculture, are the mainstays of the economy. The shift from agriculture to horticulture has changed the economic pattern of the region, as Shimla has become major centre for collection and distribution.

District Domestic Product (DDP) of Shimla at current prices has increased from 379868 lakhs in 2004-05 to 850,323 lakhs in 2011-12 showing an increase of 12.20 percent. The per capita income at current prices witnessed an increase of 9.76 percent as it increased to 85686 in 2011-12 from 44,644 in 2004-05.

No.	Indicators	2004-05	2011-12	CAGR
	GSDP in Current Prices			
	Shimla	3,79,868	8,50,323	12.20%
1	Himachal Pradesh	24,07,658	50,47,535	14.94%
	Per Capita Income			
	Shimla	44,644	85,686	9.76%
2	Himachal Pradesh	33,348	74,694	12.21%

Table 37: Economic Indicators for Shimla

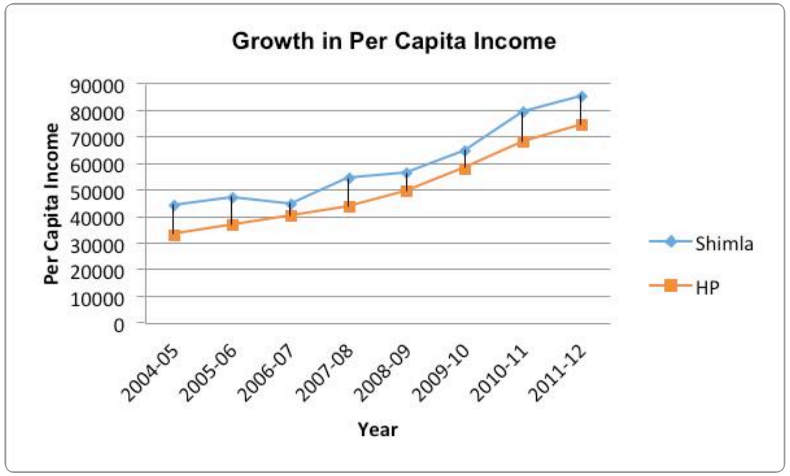


Figure 31: Growth in per capita income

3.3.4 Work Force Participation

Shimla houses major state level and district level government offices. A considerable proportion of the city's workforce is engaged in these establishments and in the tourism sector. The total working population has been close to 40% over the last three decades. The female working population in 2011 was about 25% in comparison to 75% male working population. (Table 38)

Particular	1991		2001		2011	
	No.	%	No.	%	No	%
Total Population	82054		142555		201351	
Total Working Population	33699	41	54404	38.1	84615	42
Total Main Workers	31965	94.8	52809	97	74601	88.1
Total Marginal Workers	1734	5.2	1595	3	10014	11.9
Total Non-Workers	48355	59	88151	61.9	116736	58

Source : Census of India, 1991, 2001, 2011

Table 38: Work force participation

Worker Classification

Data on nine fold classification of workers is unavailable for Shimla town. As per fourfold classification 4 percent are cultivators, 1 percent agriculture labourers and 4 percent are engaged in household industry (Figure 32). The city being a hilly tourist destination, most of the people are engaged in the service sector and it accounts for nearly 92 percent of total working population.

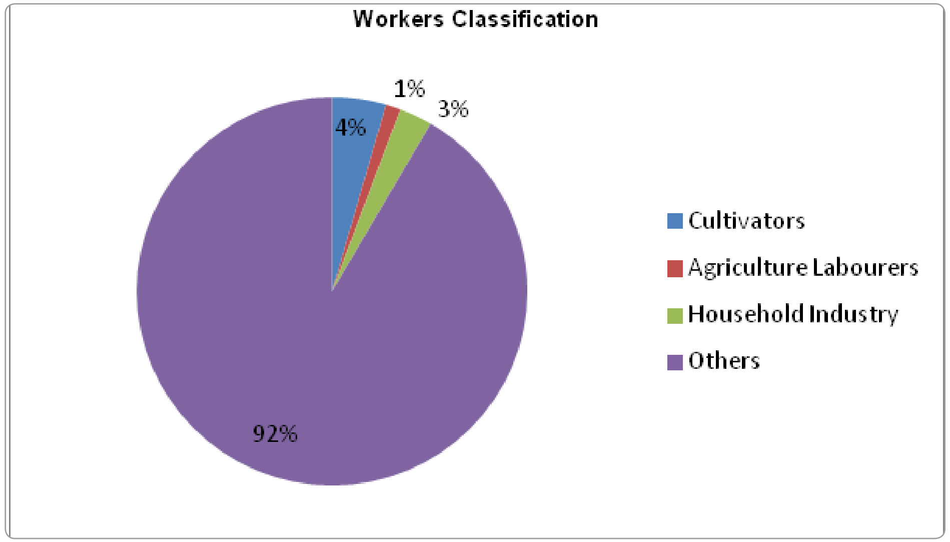


Figure 32: Worker's classification

Industries

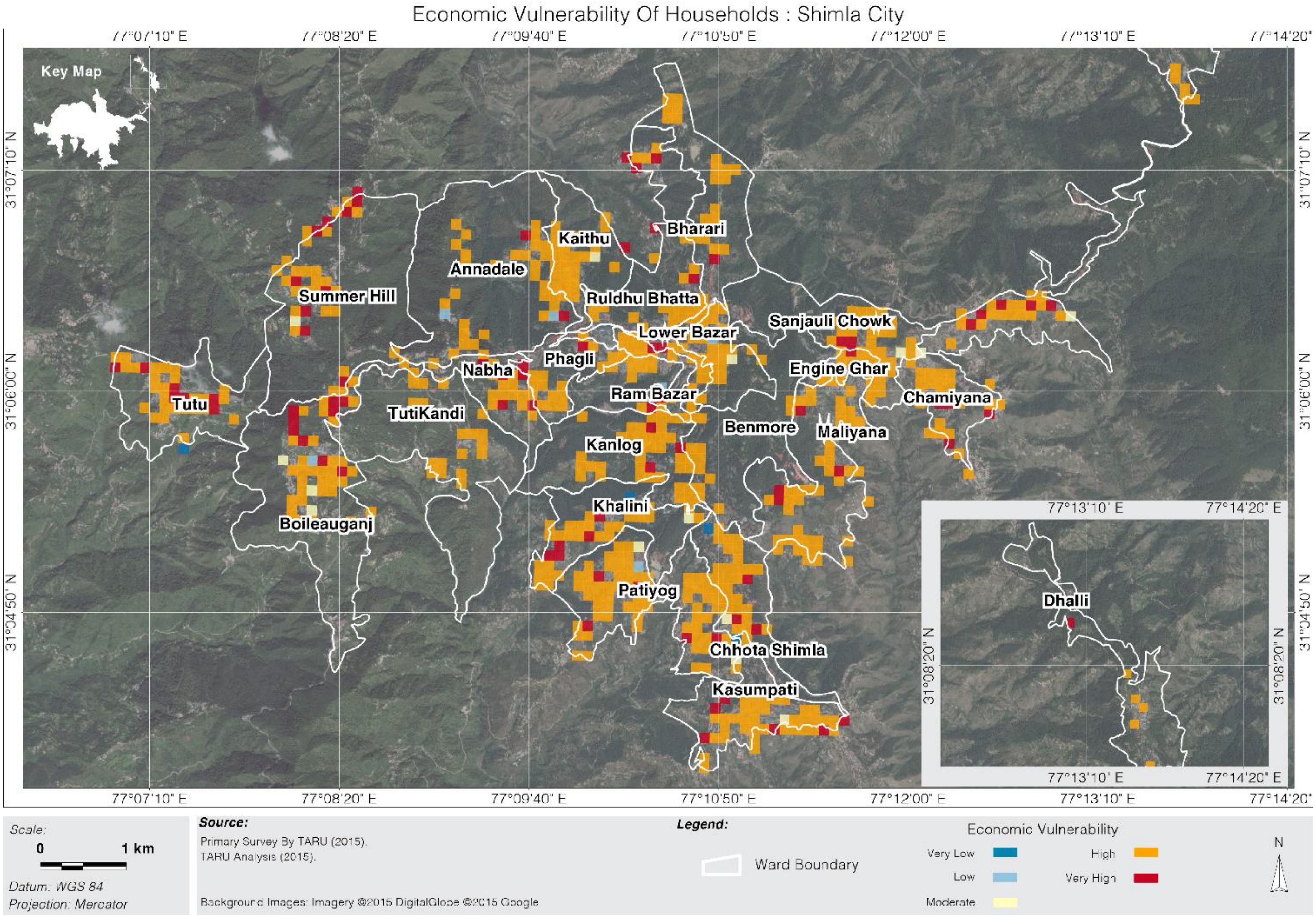
Industries in and around Shimla are not well developed like any other hill station because of the unavailability of proper infrastructure, hilly region, long distance from other cities and exorbitant cost of transportation. Traditional small scale industries like wool spinning and weaving, basket making, metal work, that use local resources are still alive without much progress. Apart from this, wood working, black-smithy, dying and manufacturing works, oil crushing, leather works, pottery, gold smithy, food processing are other small scale industries practiced in the town. The drivers for the majority of these industries are tourists and local people. Single largest industry of Shimla, tourism gained momentum after tourism has been given the status of industry by the Union Government. Incentives and subsidies offered by the government encouraged private entrepreneurs to get involved in establishment of tourism related infrastructures that ultimately provided impetus to the growth of tourism industry in state, and Shimla city in particular.

Tourism

Tourism is considered and accepted major growth driver for Himachal Pradesh and for Shimla. It has been engine of growth for the state economy including Shimla. Tourism provides direct employment opportunity in hotel and guest houses, bars and restaurants, as tourist guides, travel agency, photography etc and also generates large indirect employment. Trade, hotel and restaurants has shown average annual growth rate of 16.96 percent from 2004-05 to 2014-15 (Figure 33).

Figure 33: Growth rate of trade, hotel and restaurant

Image 20: Tourists at the Ridge



Map 29: Economic Vulnerability of Population

3.4 Summary

Vulnerability of the population and the building stock, which are the most exposed features of a city, are usually classified by the Social Scientists into two classes – intrinsic vulnerability and extrinsic vulnerability. Dhajji Dewari is a traditional construction type mainly found in Shimla and Kangra districts of Himachal Pradesh. At the time of earthquake, masonry infill panels quickly crack in plane and thus absorb the energy through friction against the timber framing and between the cracks in the fill material. Timber frame and closely spaced bracing prevents propagation of large cracks through the infill walls due to their elastic behavior. Timber bracing provide the robust boundary conditions for the infill materials to arch against and thus resist the out of plane inertial loads.

In Kath Khuni structures on the other hand, the building configuration provides adequate safety against lateral shear, but there is no apparent safety measure against overturning. In order to understand the building vulnerability, a detailed analysis of the buildings was carried out. Roofing material can play an important role in understanding the building vulnerability. On one hand, it shows the strength and durability, and on the other, it shows the crushing strength of the same.

The structural walls should be uniformly distributed in both the orthogonal directions of the building. They should be sufficient in number and strong enough to resist the expected seismic loads. Buildings having balconies with large overhanging cantilever spans, enclosed with heavy concrete parapets sustained heavier damages during earthquakes compared to the regular buildings at that elevation.

The intensity of ground motion at a particular site predominantly depends on the distance of the causative fault and the local soil conditions. The risk to the buildings increase with increasing softness of the soil. Sandy soil, saturated with groundwater, has a greater possibility of being impacted by liquefaction during earthquakes, due to the lack of firmness and jelly like characteristics.

Presence of various non-structural components such as air conditioning units, parapets and advertisement hoardings can cause injury to pedestrians as well as to building occupants and the contents during an earthquake. Even though these may not have implications for the overall structural safety of the building, they can and do contribute to earthquake related losses, as is evident from the instances of chemical spills, breakage to building contents, misalignment of piping, etc.

Population vulnerability is defined as the presence of vulnerable groups of the society and their geographical spread around the city. It can be defined as the intrinsic vulnerability of this population, using indicators such as- literacy rate, income type, dependency ratio, etc. When education and income are correlated, there is a strong positive correlation between higher education and higher incomes. This illustrates that the share of traditional economic activities are relatively lesser in the overall work pattern.

Social vulnerability on the other hand, is the intrinsic vulnerability of a household and is usually attributed by the social background of the household as well as the means of economic sustenance. Some of the locations such as- Kanlog, Maliyana, Annadale, Kaithu and Boileauganj, has households with no access path from the nearest motorable road.

Other determining indicators of social vulnerability used here are- proximity and access to the nearest fire station, hospital, access to basic services, sanitary facilities, etc, have been calculated. Wards Totu, Kanlog, Sanjauli Chowk, Chhota Shimla and Kasumpti, are the places where open defecation has been noticed due to the lack of proper sanitation facilities. This information can be used in order to identify the areas where chances of hygiene related diseases may occur, so that new sanitation schemes can be undertaken.

The population which is shown on the higher side in terms of various social, economic, population or service related vulnerability, are those that are already ‘intrinsically vulnerable’. The next chapter assesses the risk caused by the hazards and vulnerabilities discussed so far.

4

Risk Assessment

Risk is a perception as one sees it. Society looks at risk in a different way as compared to a household. Over a period of time, the perception of risk also changes. Initially, reducing the risk of disease used to be of highest importance. However currently societies have become generally safer and less tolerant of risks due to their technological advancement. Whereas, technological advances themselves sometimes brings about increased risks to the society. The benefits of new technologies appear to outweigh the risks they bring and we as a society seem to be tolerant to different risks for different reasons. The demand for increased safety at home and at workplace continues. As the risks from common events like disease diminish, the risks posed by extraordinary events, like natural hazards assume a greater significance. The level of safety that is being pursued is not specific.

In a city like Shimla, where natural hazards pose more risk compared to other hazards like disease or epidemic, it is important to understand the risk the society and the individual is exposed to. In this exercise, an attempt is made to calculate the risk posed to the society at large, compared to a household or individual risk. A far more deep understanding of the society, households and individuals is needed in order to arrive at such calculations. Nevertheless, a detailed analysis of a ward has been done in terms of understanding the hazard, vulnerability, risk, preparedness, based on which an emergency management plan has been proposed.

After assessing the hazards and vulnerabilities in the second interim report, in this chapter, risk is calculated. The overall task of risk management must include both an estimation of the magnitude of a particular risk and an evaluation of how important to us the risk is. The process of risk management therefore has two parts:

a) Risk Assessment: The scientific quantification of risk from data and understanding of the processes involved.

b) Risk Evaluation: The social and political judgement of the importance of various risks by the individuals and communities that face them. This involves weighing perceived risks against potential benefits and also includes balancing scientific judgements against other factors and beliefs.

A detailed methodology of calculating risk has been discussed here. For all calculation purposes, risk is defined as the product of hazard and vulnerability.

Risk=Hazard x Vulnerability

However, Hazards and Vulnerabilities are measured in numbers (no units). Due to practical problems of estimating the damages/losses, usually risk assessment is limited to people, buildings and infrastructure. However, in this exercise, we have included the infrastructure as well as the economic losses the city of Shimla will suffer in case a scenario event occurs. In order to put a value on the assets damaged, risk is also defined as:

Risk=Hazard x Vulnerability x Amount

Where, Amount is the replacement cost of the existing infrastructure.

Acceptable risk: a risk for which, for the purpose of life or work, we are prepared to accept the risk as it is with no regard to its management. Society does not generally consider expenditure in further reducing such risks justifiable. Once the risks are known, the managers will have to address the costs of reducing a risk in terms of the benefits (actual risk reduction) that would result. Some communities have chosen to simply live with a risk because the costs of mitigating its consequences are prohibitive, and eliminating the risk is unthinkable. For example, the use of the automobile highlights the cost-benefit scenario.

At present, over a million road traffic fatalities occur throughout the world each year, which obviously presents a greater risk. With increased cost, car manufacturers could easily make their cars much safer, and fatality rates could be reduced significantly. However, such a cost would make automobiles too expensive for the average consumer. Thus, we accept the loss of over a million lives per year for the benefit of having affordable cars. Even if manufacturers spent the money to make cars completely "safe" for occupants, there would still be an inherent risk associated, as indicated by the great number of fatalities that are caused by pedestrians who are hit by cars.

Tolerable risk: a risk that society is willing to live with so as to secure certain net benefits with the confidence that it is being properly controlled, kept under review and further reduced as and when possible.

Effective risk management requires information about both the magnitude of the risk faced (risk assessment) and on what importance society places on the reduction of that risk (risk evaluation).

Risks are often quantified in aggregated ways. Such gross risk estimates can be useful for comparative purposes, but usually conceal large variations in the risk to individuals or different regions. The importance a community places on the risk of a natural disaster is likely to be influenced by the type and level of other everyday risks it faces. The process of economic development needs to incorporate a risk mitigation strategy because traditional ways of coping with environmental risks are otherwise likely to be lost.

Risk is perceived differently by different individuals and different groups. Those with regular access to news media are likely to be more aware of the environmental risks they face than others, but they may also as a result overestimate the likelihood of uncommon risks such as natural disasters. Risk perception is also influenced by the degree to which a hazard is considered controllable or its effects preventable and by the extent of the 'dread' an individual feels towards it.

The acceptability of a certain level of risk to individuals and societies appears to increase with the benefits which are obtained from exposure to it, and to be much greater where exposure to the risk is voluntary (as in sports) than where it is involuntary (like natural disasters). The acceptable level of risk also appears to decrease over time as more people become exposed to a particular type of risk.

For many risks, mitigation can best be handled at the level of the community because the exposure of the community is greater than that of the individual, and because protection often requires collective, sometimes large-scale action. In the 20th century the scale of natural disasters (including famine) has been much greater than that of technological disasters (apart from wars), both in terms of the total number of casualties and the numbers of high casualty events.

Risk maps attempt to show the spatial or geographical distribution of expected losses from one or more natural hazards. Because of the way natural hazards occur, the presentation of annual risk, as defined above, is not necessarily the most useful. Instead, several different ways of presenting losses are commonly used which includes:

a. Scenario Mapping: presents the impact of a single hazard occurrence. Scenario mapping is often used to estimate the resources likely to be needed to handle an emergency. The number of people killed and injured, and the losses arising in other elements is estimated. From these can be estimated the resources needed for medical attention, to reduce disruption, accommodate homeless, and minimize the recovery period.

b. Potential Loss Studies: maps the effect of a probably expected hazard occurrence across a region or country shows the location of communities likely to suffer heavy losses. The effect of the hazard in each area is calculated for each of the communities living within those areas to identify the 'Communities Most At Risk'. This shows, for example, which towns or villages are likely to suffer highest losses, what should be the priorities for loss-reduction programs, and who are likely to need most aid or rescue assistance in the event of a major disaster.

c. Annualized Risk Mapping: is the calculation of the probable level of loss occurring from all levels of hazards over a period of time. The probability of each level of hazard occurring within that unit time period is combined with the consequences of that level of hazard to generate the expected loss within that time. Summing up the losses over all levels of hazard gives the total loss expected within a period of time. The map indicates expected losses over both time and space. With sufficient detail in the calculation, the likely effect of mitigation policies on reducing earthquake losses can be estimated, and costed. The relative effects of different policies to reduce losses can be compared or the change in risk over time can be examined.

Annualised Risk is the product of vulnerability and hazards expressed as a risk. However, the actual number does not lead to any inference, so risk is expressed as annual risk. Annualised Risk means, how much risk a household or neighbourhood or a society is posed to in a year. Instead of directly taking the product of hazard and vulnerability, probability of the hazard happening in a given year is also considered in this calculation. For example, a person experiencing a flood in a year will depend on the monsoon season in that geographic area.

It doesn't only depend on the exposure and the vulnerability of that person. If the return period of the flood is 10 years, the probability of the flood happening in one year becomes 1/10, i.e. 0.1. Similarly, the probability of an earthquake of RP 50 years is 1/50 i.e. 0.02. By bringing in this probability we can calculate the annualised risk of each hazard and also the cumulative risk of the all hazards.

Advantages of the annualised risk:

For making the relief and rehabilitation process more self-reliant, it is advised that the household resilience be increased. Household capacity and reliance can be increased by –

1. providing measures for sustainable livelihoods,
2. retrofitting houses,
3. providing escape routes and equipment
4. by encouraging households to insure lives and property

Building RVS scores

Risk classification:

- **Class A**: High-risk condition with highest priority for mitigation and contingency planning (immediate action)
- **Class B**: Moderate to high-risk condition with risk addressed by mitigation and contingency planning (prompt action)
- **Class C**: Risk condition sufficiently high to give consideration for further mitigation and planning (planned action)
- **Class D**: Low-risk condition with additional mitigation contingency planning (advisory in nature)

4.1 Population Risk

Estimation of the potential loss of lives has been calculated using the peak ground acceleration (PGA) of an earthquake of 2500 year return period. Number of expected casualties was calculated for both mid night and day time scenario as the population under is higher at night time in comparison to day time when most of the people are awake and they have the possibility to come out of the buildings to an open space. Similarly, population causality risk for landslide and other hazards has been calculated and then combined. As per Table 39, if any earthquake happens at night, roughly 20466 people will perish within the city, while if the quake happens during the day time, the number will be 5116. This also indicates that the residential buildings are more vulnerable compared to outdoors. So in an event of an earthquake, it is always advised to get to a safer open space, compared to practicing Duck – Cover – Hold (DCH).

Cumulative population risk has been carried out by combining the seismic risk, landslide risk and urban fire risk. Other risks, viz., forest fire risk, urban heat island risk, hailstorm, etc could not be simulated for Indian conditions. Further research is required for doing so. So combining the three above mentioned risks, annualised cumulative risk has been calculated and represented in the Map 30. The highest risk class, 'very high' shows that the households within this 100 sqmt grid have a very high probability of getting impacted by one or more of the hazards while the households on the 'moderate risk' show that they have a moderate probability that they may get effected by one of the hazards.

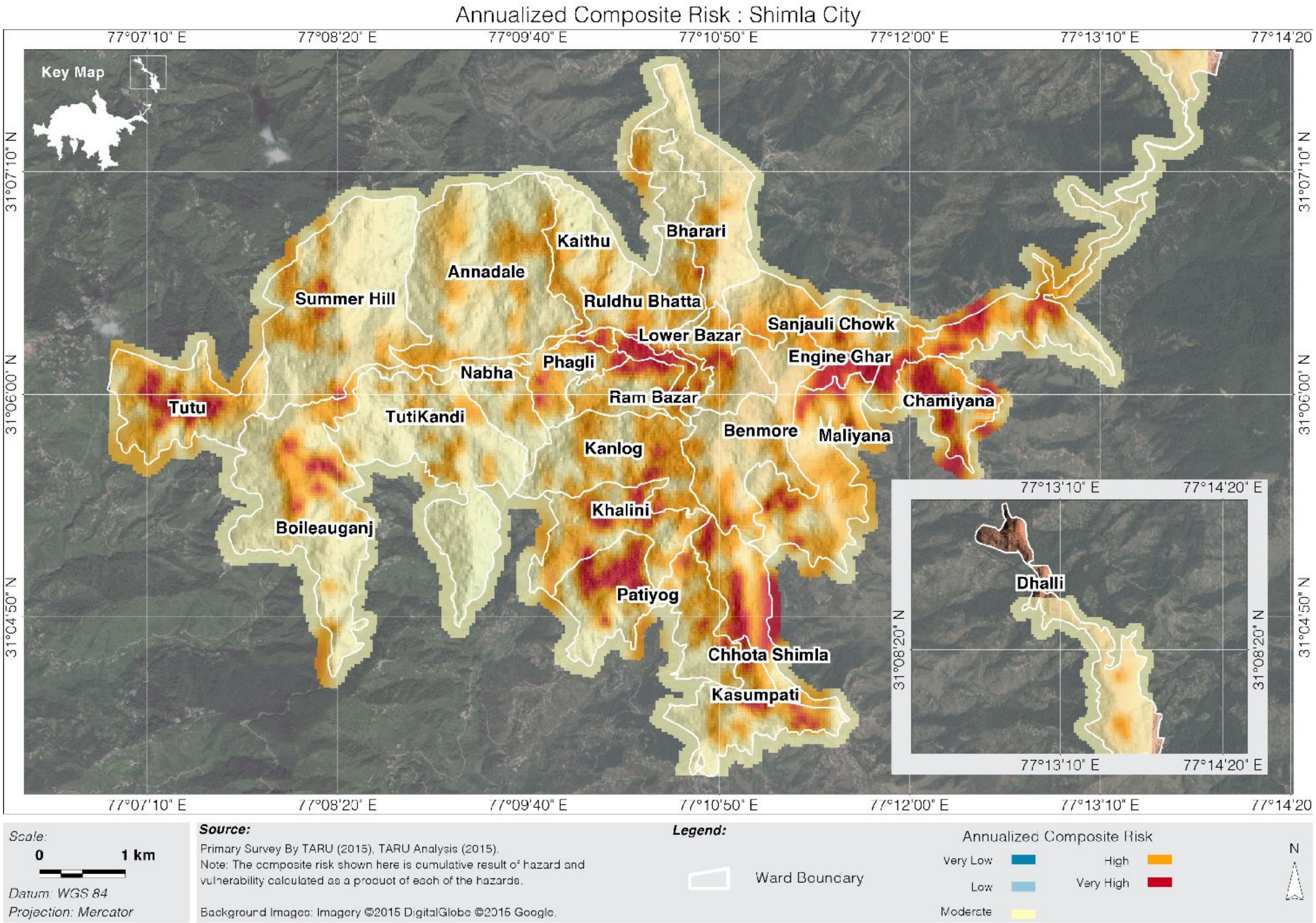
Time of occurrence	Deaths in collapsed houses	Deaths in partially collapsed houses
Midnight (sleeping)	40%	20%
Daytime (working)	10%	5%

Source : Arya 1992

Table 39: Assumed Death Rates for Earthquake

4.2 Building Risk

Based on the building vulnerability and the hazards that building is exposed to, an annualised building risk has been calculated. Buildings with lower rapid visual screening (RVS) score tend to get more damaged compared to the buildings with higher RVS score. As has been indicated in Error! Reference source not found. zones in very high risk zone tend to fail more when exposed to an earthquake or landslide compared to the buildings in the lower risk zones.



Map 30: Annualized Composite Risk

4.2.1 Fragility Curves

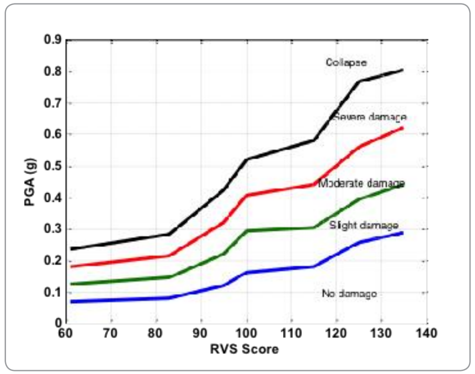
Fragility curves were developed for reclassified five predominant building typologies. Fragility curve represents the expected level of damage of a building under different PGA values. The damage parameters (D) have been classified as no damage (D<0.2), slight damage (0.2<D<0.4), moderate damage (0.4<D<0.6), heavy damage (0.6<D<0.8) and collapse (D>0.8). The PGA values with respect to RVS scores for damage categories have been determined from the fragility curves. The state of damage of all types of buildings can be found out from fragility curve shown in the figure, provided that the PGA value of the region and RVS score of building is known.

Fragility curve shows (Figure 34) that a building with low RVS score means it is a highly vulnerable building and will suffer more damage at low intensity of earthquake only (low PGA value). For RC frame structures, a building with RVS score of 70 will suffer D3 or higher category of damage due to earthquake capable of producing PGA value of more than 0.14g.

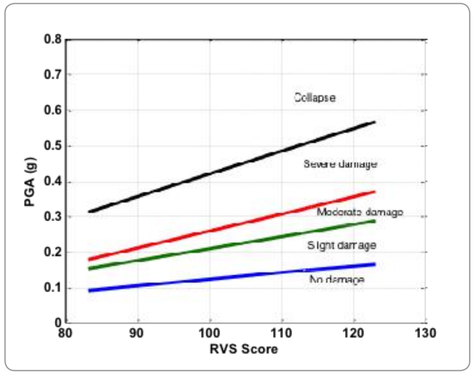
Fragility curve of brick masonry building shows that buildings having RVS score of 85 will suffer D4 to D5 category of damage at the sites where PGA exceeds above 0.18g. A building of low vulnerability, having RVS score of 120 will sustain high intensity of earthquake. It will incur damage of grade D1 and D2 only, even at the PGA values of 0.15g to 0.27g.

Stone masonry and rammed earth buildings may receive sever damage (D4 and D5) at PGA values of 0.1 g and 0.16g only even though their RVS score vary from 85 to 110. Rammed earth wall being brittle in nature receive damage at early stage of deformation due to lateral forces. Stone masonry buildings donot have interlocked masonry units due to undressed/ rounded stone used in wall construction which may collapse even in case of minor shaking in the low intensity earthquakes.

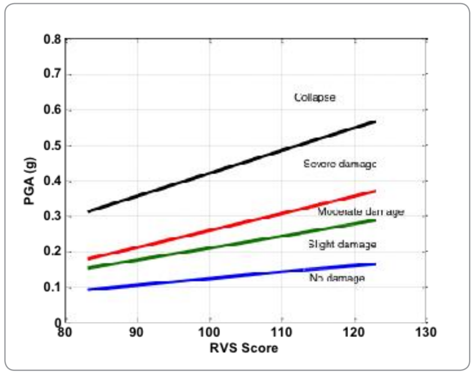
Hybrid and other buildings will sustain large earthquakes without being majorly damaged. Most of the buildings will suffer D1 or D2 category of damage only.



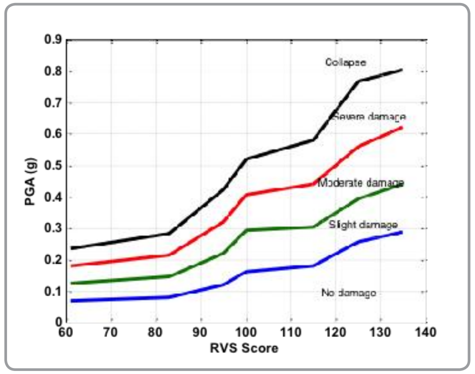
RCC Buildings



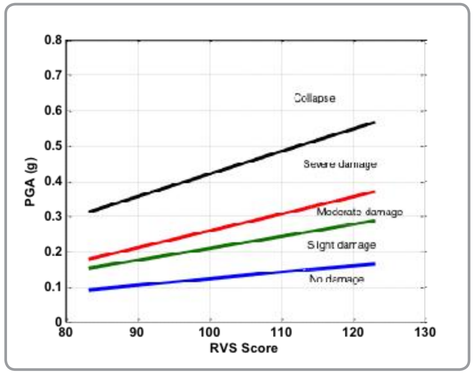
Brick Masonry Buildings



Stone Masonry Buildings

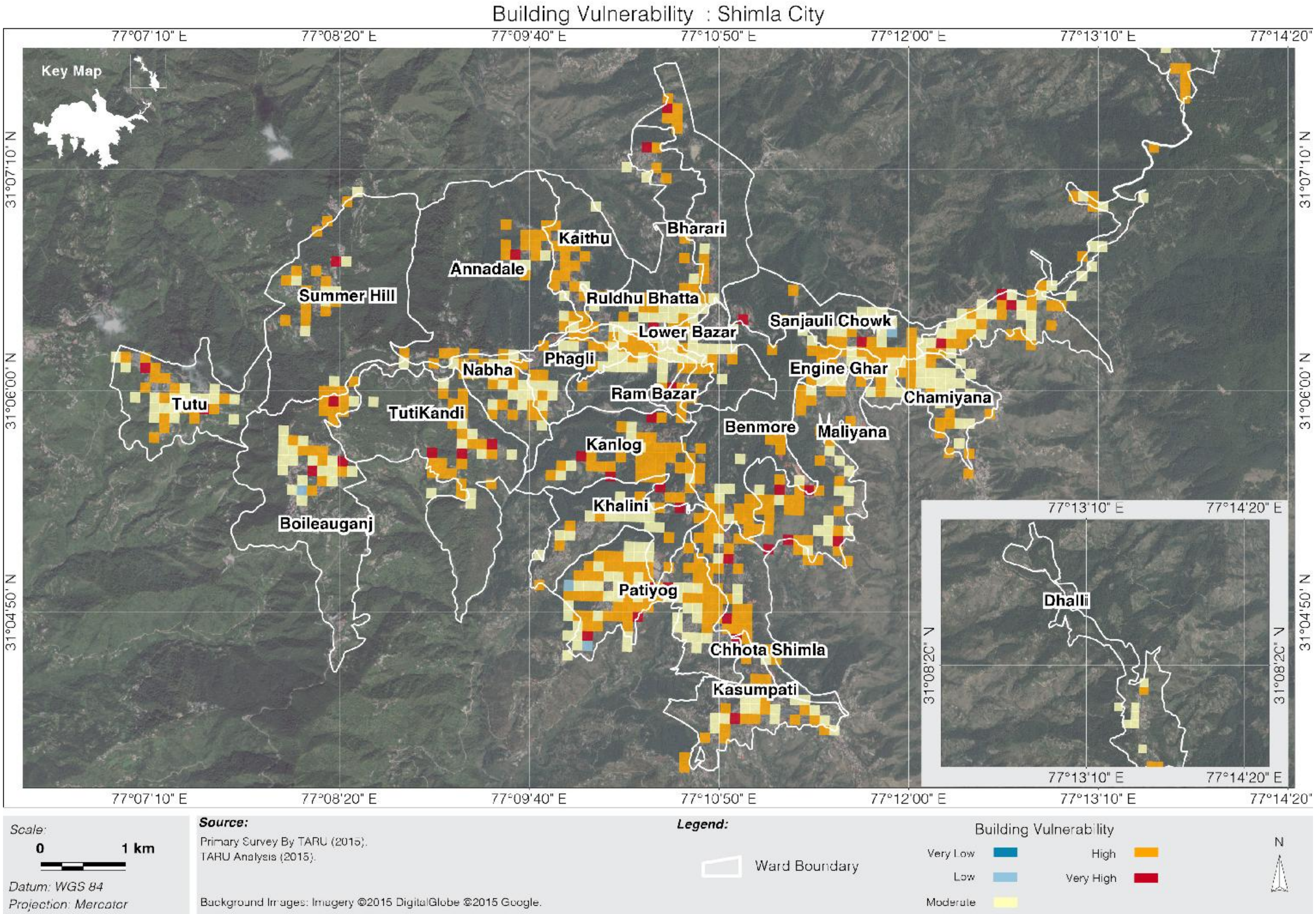


Rammed Earth (Traditional) Buildings

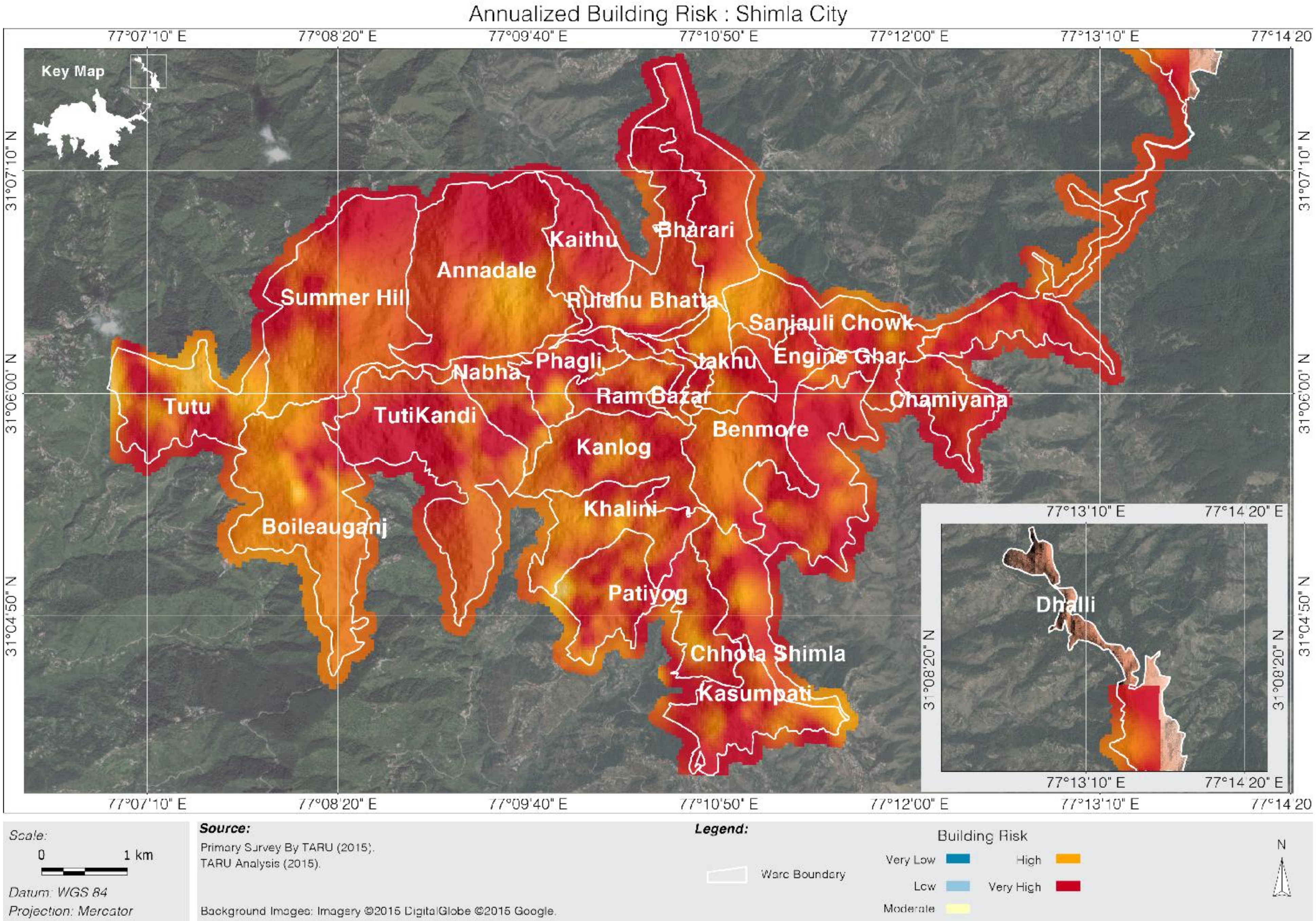


Rammed Earth (Traditional) Buildings

Figure 34: Building fragility curves



Map 31: Building vulnerability of Shimla city



Map 32: Building Risk Assessment

Rammed earth buildings are more fragile than other building typologies. Rammed earth and stone masonry buildings are expected to get severely damaged or collapse completely in the event of low intensity earthquakes as well. Hybrid buildings demonstrate better performance in earthquake and are only partially damaged.

These conditions may also vary based on the season of the year when the earthquake occurs– dry season or monsoon season. Monsoon season has more earthquake triggered landslides, which may cause additional building damage and loss of lives. In this study, the complexity of the multiple events occurring at the same time has not been considered.

The damage which the existing buildings within the city may experience in an event of an earthquake with 2500 year return period are tabulated below. The number may differ from analysis to analysis, however, there is a presence of risk, which is important to the current study.

Grade of Damage	Description of Damage
Grade 1(D1)	Slight damage fine cracks in plaster: fall of small pieces of plaster.
Grade 2 (D2)	Moderate damage small cracks in plaster: fall off fairly large pieces of plaster: pan tiles slip off: cracks in chimneys, parts of chimney fall down.
Grade 3 (D3)	Large and deep cracks in plaster: fall of chimney.
Grade 4 (D4)	Gaps in walls: parts of buildings may collapse: separate parts of the buildings lose their cohesion: and inner walls collapse.
Grade 5 (D5)	Total collapse of the buildings.

Table 40: Description of damage grades

Building typology	Total buildings	Building damage	Damage ratio
RC frame	416	130.1	3.2
Burnt brick	35929	13358	2.6
Stone masonry	2738	1089.3	2.5
Rammed earth	1314	1314	1.0
Hybrid	1073	341	3.1

Table 41: Damage ratio in building typologies

4.3 Infrastructure Risk

Water lines will be broken by landslides and ground shaking leaks precious water into the streets, and the damaged water supply system cannot provide more water to the city. Damage to the electrical transmission system causes power cuts throughout Shimla. In the immediate aftermath, residents will not fully comprehend that Shimla is completely isolated. Communication options will be severed due to landslides and building collapses which blocks road access. It may take days or weeks to bring in emergency water and power—and much longer to fully restore all the systems.

Water, electricity, communication systems and roads are the basic infrastructures that serve Shimla's residents. These are called lifelines because people depend on them for life-sustaining services. This is especially true for the city of Shimla, where loss of transportation systems and clean water in particular are life-threatening. Shimla's water, electrical power, communication systems and roads are all vulnerable to earthquakes. When earthquakes strike, ground shaking can stretch and compress buried pipelines, conduits and bridges, and can damage unsecured equipment. Landslides rip through pipelines, topple electrical poles, undermine and bury roads, and also blocks rivers. Bridge decks can be pulled off from their abutments and sandy saturated soils can liquefy and settle or move, damaging cables, pipelines, dams and equipment. Ground shaking and ground failure affect infrastructure, water mains, electrical transmission and distribution systems, and roads. This damage can be minimized by actions taken ahead of time to make pipelines, bridges and roads more robust.

In order to assess the damage that may be caused to the infrastructure systems, a detailed infrastructure mapping has been carried out (as part of the elements at risk database). Risk has been calculated based on individual infrastructure's exposure to high hazard zones. However, probability of the failure of the infrastructure in a given year cannot be estimated based on the existing data conditions. Maps or database of the physical infrastructure is not available with the municipal corporation. Under these circumstances, hotspots (where additional strengthening or backup plans need to be implemented) have been identified. Higher preference has been given to the trunk infrastructure compared to the distribution networks. Shimla may be isolated in terms of supplies and communication because of the following:

1. It is remote, and roads leading to and from Solan and Kufri may lack capacity and are subject to blockage by landslides and debris from collapsed buildings;
2. Shimla will be divided into 3-4 islands – Totu; areas from RTO to High Court; Secretariat – Kasumpti - Chhota Shimla; Sanjauli - Chamiyana - Engineghar; Dhalli.
3. Many of its slopes are unstable (ref. landslide hazard maps) during earthquake shaking, and the resulting landslides will damage utility systems, roads and streets;
4. Hillside construction is exceptionally vulnerable (Sanjauli, Kasumpti, Dhalli, Totu) to damage from shaking, and collapsing buildings will damage electrical and communications systems and block streets; and
5. The city's dense, urban population is uniquely dependent on infrastructure for food, water and medical care.

4.3.1 Water Supply

The city may suffer a major jolt with the failure of the main trunk lines that supply water to the city. These trunk lines are of varying diameter and exposed in many parts of the city. The water supply network is a critical element of civil infrastructure system. Its complexity of operation and high number of components mean that all parts of the system cannot be simply assessed. Earthquakes are the most impacting natural hazard for a water supply network, and seismic risk assessment is essential to identify its vulnerability to different levels of damage and ensure the system safety. A moderate landslide or a PGA more than 0.3 will damage much of the existing water supply network. Partial destruction of the pipelines does not mean the destruction of the entire network of a system. For a particular network topology, the destruction of the some pipelines may greatly reduce the performance of system, while others hardly have a significant impact on the overall performance of the system.

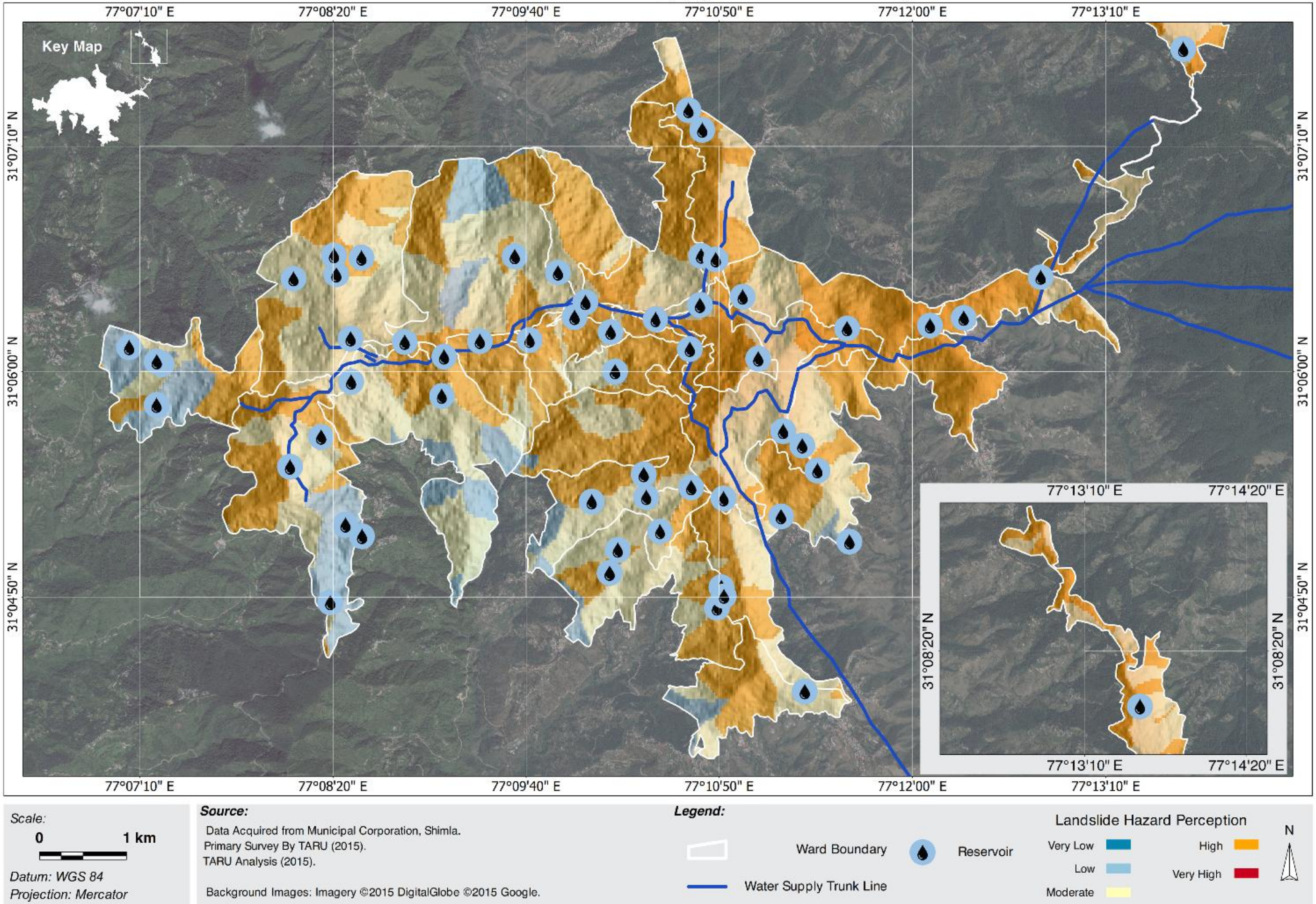
Risk Class	Damage degree	Phenomenon of damage
Moderate Risk	Slight damage	Pipes and fittings are largely intact, the individual joint fillers may have a slight crack, which will result in slight leakage
High Risk	Moderate damage	Pipes almost have no damage, and the individual joints have smaller cracks. It is easy to leak, can be repaired easily.
Very High Risk	Serious damage	Pipes, fittings and sockets and other accessories are damaged seriously, and joint fillers are basically crushed. Leaking seriously and it is difficult to repair.

Table 42: Phenomenon of damage

The treated water pipelines in Shimla traverse a slope which often has active landslides. Distribution mains and local distribution lines cross numerous areas where landslides could occur or have occurred. The treatment structures and equipment can be damaged or dislodged by earthquake shaking, rendering them useless until repairs are made or replacements installed. The components comprising the electrical substations at the water treatment plants and at the pump locations are not currently anchored for earthquake motions. Even if the pipelines remain intact, electric system failures, and failures at the treatment plant substations, would cripple the municipal water system. As a result there would be no electricity to power pumps, chemical processes, flow controls and communications. Because the first set of raw water pumps are not connected to emergency generators or diesel pumps, the water supply is limited to the amount already in the system.

The electric pumps that carry treated potable water to the main reservoir at AG Office through other feeder lines may get damaged. The stored diesel fuel at the pumping stations varies in amount, that can last for a few days to three weeks. However, because diesel motors and fuel tanks are vulnerable to shaking damage if not anchored to resist earthquake forces, they would not be operable without repairs. Chemicals needed to disinfect the water supply (salt and alum) are to be stored adequately, so that the same can be distributed to individual households, in order to ensure that water from various streams/sources throughout the city can be brought to service.

Landslide Hazard - Water Supply Network : Shimla City



Map 33: Water supply network and landslide risk

4.3.2 Roads Railway Network

In the event of an earthquake, road access to Shimla, and circulation within the city, would be lost. Multiple slides would sever the NH-22 and the road from Solan and airport, requiring heavy equipment and construction of temporary bridges. Repairing slides and bridge damage to establish even minimal access could take weeks, even with measures to speed repairs by allowing work at multiple locations, such as by transporting earthmoving equipment to intermediate points.

Collapsed buildings with trapped victims would not be removed from streets until search and rescue operations are complete. Emergency vehicles, and lorries with critical equipment and supplies, would not be able to move within or through the city for weeks. Search and rescue and life-saving medical care would be impeded. Unless these damaged stretches are repaired, moving of emergency supplies and personnel can be done only through helicopters.

Shimla depends on two-lane roads for supplies and services needed for day-to-day survival. The most important road is the national highway linking Shimla to the other parts of the state/country, especially NH-22 from Chandigarh. These roads traverse steep slopes where landslides and rock falling frequently occur, blocking the way. These roads have several narrow stretches carved out of hills. The system of urban streets within the city is also critical to movement of supplies and people. Shimla's relatively few major urban roads and streets are narrow and congested on weekdays by automobiles, motorbikes, pedestrians, and parked vehicles.

Parking on streets being a routine, circulation within the city will be vulnerable to landslides and blockage by collapsed buildings. Debris from damaged and collapsed buildings would smash cars and block streets, connecting walkways and stairs. It could take several weeks to open major urban roads and streets to allow distribution of critical equipment and relief supplies brought in by helicopter by lorries/trucks. It would take much longer for street clearing operations to reach some areas of the city. The overlay of the earthquake risk and the road network has been shown in the Map 34.

4.3.3 Sewerage / Nalah Network

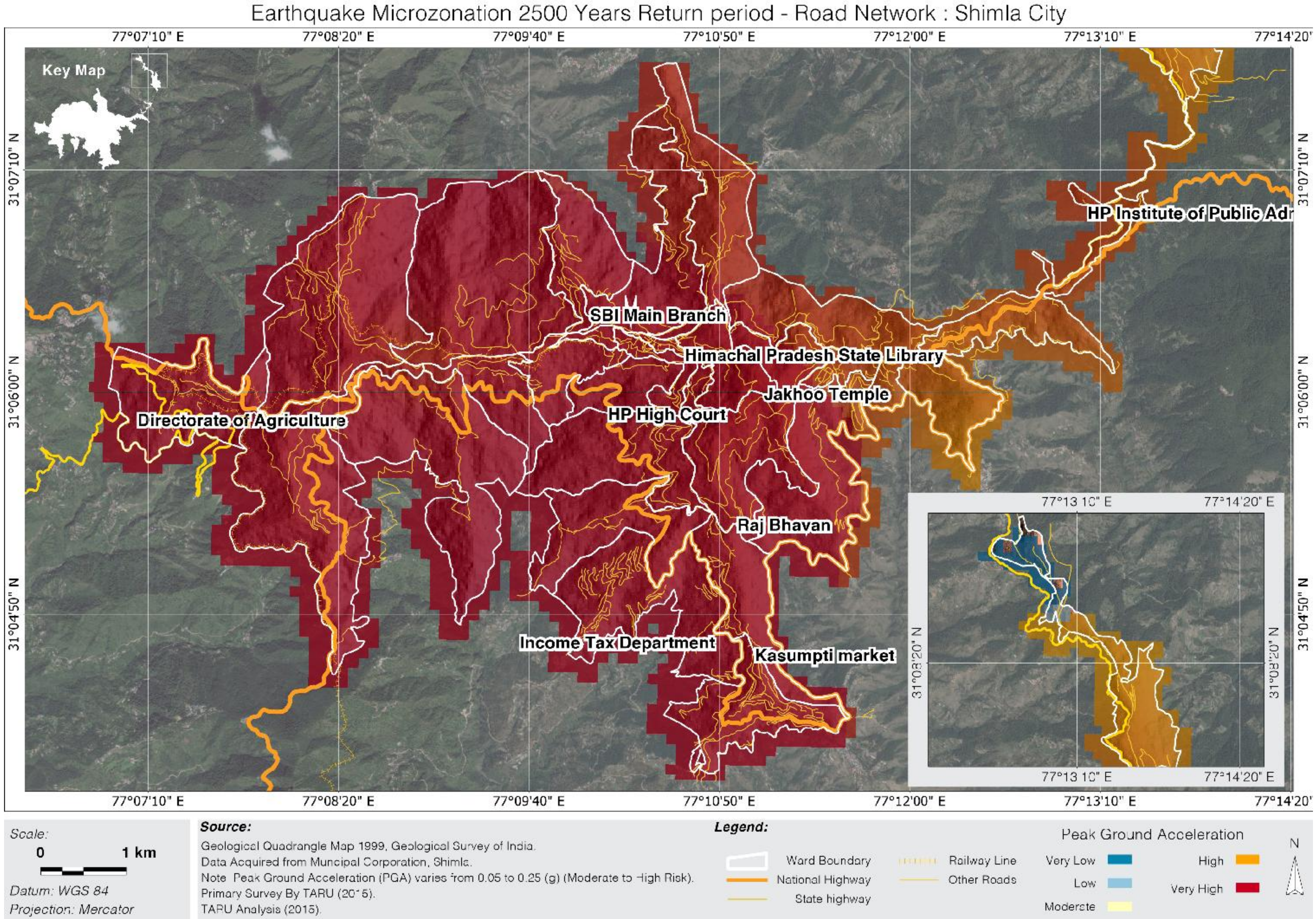
Current sewerage system depends heavily on the existing natural drains/nalahs. With earthquake and the triggered landslides, many of these nalahs will be disturbed and the waste water will be flowing on the roads. Landslides and debris blocks the system of street-side wastewater channels. Ground movement breaks drains, culverts and sewer pipes, and debris from collapsed buildings and landslides will block them. Interruption of the drainage system would divert waste and surface runoff from rainfall onto the streets, into low-lying areas and natural channels. Uncontrolled waste would contaminate drinking water supplies.

Some of the areas, where these nalahs will be disturbed are shown in the Map 35.

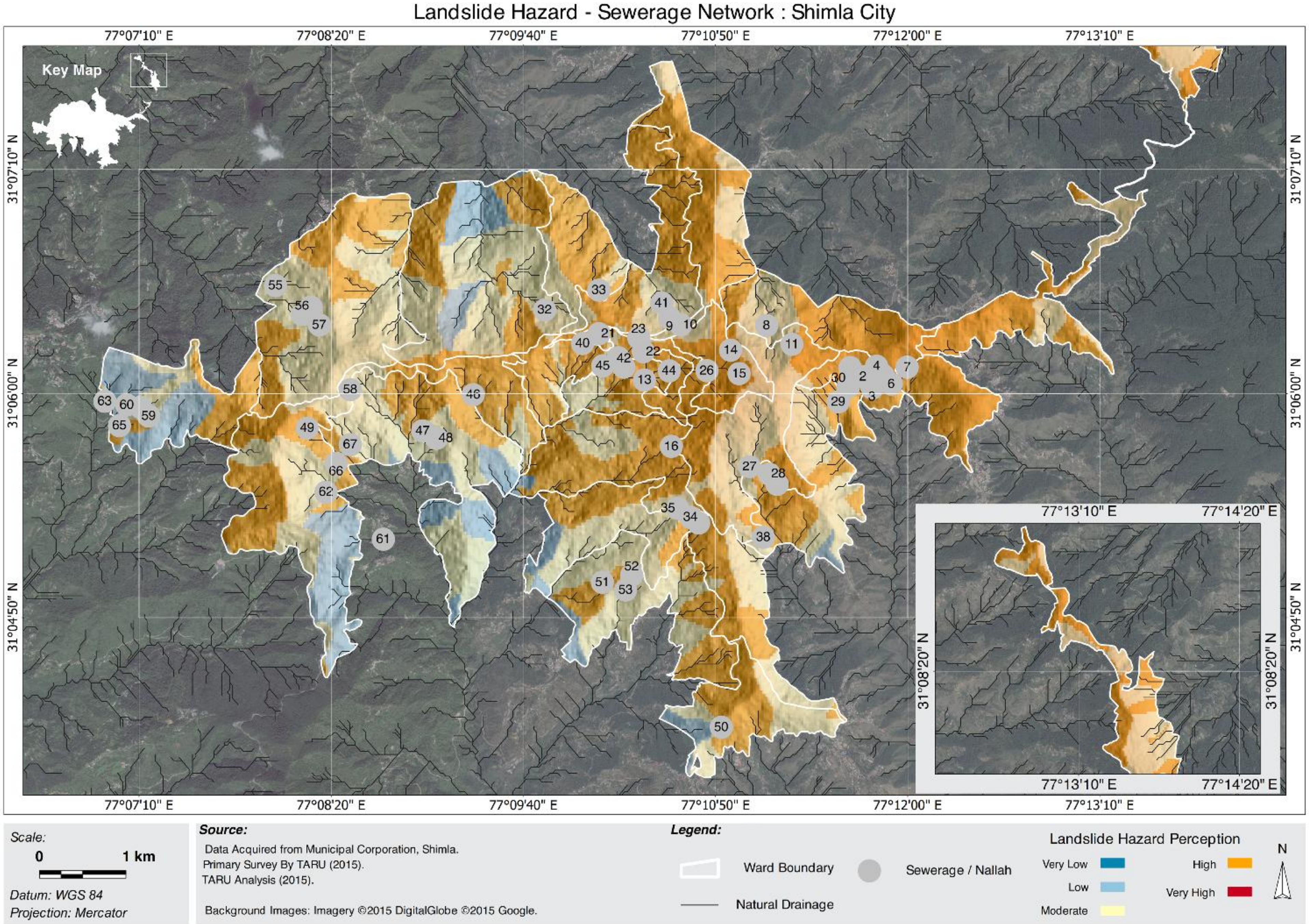
4.3.4 Cooking Gas, Petrol and Diesel

There are five LPG godowns in the city (Boileauganj, Tolland, Lakkar bazar and one each in Tutikandi and Bharari) and about 6 fuel dispensing stations. With the road transport being cut off because of the debris and landslides blocking the way, the fuel supplies from outside the city may be disturbed. Whatever is stored in these stations will last for few days or weeks and the fuel will be scarce till the road network is restored. Damage to roads and congestion would limit supplies severely for weeks. Lack of fuel would limit local generators' capacity to deliver electricity and would hamper repairs that are dependent on the generators and heavy equipment. Fuel for emergency generators and diesel pumps at the water treatment plant must be delivered by helicopter until access roads are reopened. Automobiles, lorries and equipment require petrol or diesel to operate, and backup generators require diesel. Fuel delivery depends on lorry tankers driving from Solan to reach depot areas at Shimla.

In this scenario, cooking gas supplies would diminish quickly because of road closures. The lack of gas to cook food and boil water would have health implications. Residents use liquefied petroleum gas (LPG) from individual high-pressure cylinders for cooking fuel. These cylinders will be supplied once the roads are functional.



Map 34: Road network and earthquake risk



Map 35: Landslide hazard over nalahs

4.4 Economic Risk Assessment

1. Those with money and vested interests can influence the process of determining the acceptability of risk. Because the process of determining risk acceptability (including mitigation spending and regulatory practices) is influenced by politics and may be shaped by political ideology, it is possible for corporates or interest groups to lobby and influence decision-making.

This can be seen in case of hazards such as handguns and assault rifles, environmental degradation, soil and water pollution, and construction in hazardous areas. Increased citizen participation in the process can decrease such injustice. By increasing the decision-making power of the general public, a more democratic outcome (although not guaranteed) is possible.

2. Assigning a dollar figure (in cost–benefit analysis) to human life is unethical and unconscionable. This is primarily a factor related to involuntary risks. To the individuals whose lives are being placed at risk, any dollar figure will seem low or inappropriate as a trade-off for the acceptance of the risk. Many people would (understandably) feel that their life is too great a price to pay for the existence of any involuntary risk.

It is often the poor who must live in the highest risk areas of a floodplain, under high-tension power lines, or along the highways. These people bear a larger share of the population risk, while many others enjoy much lower risk levels from those particular hazards, even though they enjoy a disproportionate amount of the benefits. Thus, risk communication and public participation are important to counteract these injustices.

The cognitive processes that dictate the determination of 'price of a human life' are often different for voluntary risks. As the automobile safety example illustrates, people are willing to accept a certain increase in risk to their own lives for the benefit of more affordable products. How much more affordable differs from person to person. But, as shown by relatively recent lawsuits against tobacco companies by smokers who became ill, people may be unwilling to accept some voluntary risks despite previous knowledge about those risks.

Because of the controversial nature of placing a value on life, it is rare that a risk assessment study would actually quote a dollar figure for the amount of money that could be saved per human life loss that is accepted. Post-event studies have calculated the dollar figures spent per life during a crisis, but to speculate on how much a company or government is willing to spend to save or risk a life would be extremely unpalatable for most.

3. Risk management is usually an undemocratic process, as those who may be harmed are not identified or asked if the danger is acceptable to them. It is not difficult to recall a case in which a vulnerable or disadvantaged group of people was exposed to a risk whose benefits were enjoyed by others.

Many toxic waste dumps are located in the impoverished parts of towns, cities, and states, although the people in those communities had little say in deciding the location for dumping such materials. Related to this injustice is the reality that the impoverished are usually less able to avoid such risks, as the property or jobs available to them are often associated with these very same risks.

It is often the poor who must live in the highest risk areas of a floodplain, under high-tension power lines, or along the highways. These people bear a larger share of the population risk, while many others enjoy much lower risk levels from those particular hazards, even though they enjoy a disproportionate amount of the benefits. Thus, risk communication and public participation are important to counteract these injustices.

4.5 Summary

In a city like Shimla, where natural hazards pose more risk compared to other hazards like disease or epidemic, it is important to understand the risk the society and the individual is exposed to. Risks are often quantified in aggregated ways. Such gross risk estimates can be useful for comparative purposes, but usually conceal large variations in the risk to individuals or different regions. The process of economic development needs to incorporate a risk mitigation strategy because traditional ways of coping with environmental risks are otherwise likely to be lost.

Estimation of the potential loss of lives has been calculated using the peak ground acceleration (PGA) of an earthquake of 2500 year return period. Number of expected casualties was calculated for both mid night and day time scenario as the population under is higher at night time in comparison to day time when most of the people are awake and they have the possibility to come out of the buildings to an open space. If any earthquake happens at night, roughly 20466 people will perish within the city, while if the quake happens during the day time, the number will be 5116. Cumulative population risk has been carried out by combining the seismic risk, landslide risk and urban fire risk. Other risks, viz., forest fire risk, urban heat island risk, hailstorm, etc could not be simulated for Indian conditions.

Moreover, on the basis of the building vulnerability and the hazards they are exposed to, an annualized building risk has been calculated. As per the analysis, whereas, stone masonry and rammed earth buildings may receive severe damage, hybrid and other buildings will sustain large earthquakes without having any major damage. Rammed earth buildings are more fragile than other typologies. However, the impact and the damage incurred also depends on the season during which the earthquake occurs. Therefore, for a better understanding, such damages have been graded and mapped in this study.

Risk to the infrastructure includes- breaking of the water lines by landslide and ground shaking, damage to the electrical transmission system and blockage of roads. These being the lifelines of the residences of Shimla, infrastructural risk can also be life-threatening. In order to assess the damage that may be caused to the infrastructural systems, a detailed infrastructure mapping has been done.

Image 21: A vulnerable building at Shimla exposed to hazards

5

Risk Reduction Measures

5.1 Structural Mitigation

Resistant Construction.
Building Codes and Regulatory Measures.
Relocation.
Structural Modification.
Construction of Community Shelters.
Construction of Barrier, Deflection of Retention System.

5.2 Non-structural Mitigation

Regulatory Measures.
Community Awareness and Education Programs.
Behavioural Modification.
Risk Transfer, Sharing, and Spreading.

5.3 Summary

5.1 Structural Mitigation

Structural mitigation measures are those that involve or dictate the necessity for some form of construction, engineering, mechanical changes or improvements aimed at reducing hazard risk likelihood or consequence. They often are considered attempts at "man controlling nature" when applied to natural disasters. Structural measures are generally expensive and include a full range of regulation, compliance, enforcement, inspection, maintenance, and renewal issues.

Although each hazard has a unique set of structural mitigation measures that may be applied to its risk, these measures may be grouped across some general categories. Each category has been described with examples of how the mitigation type would be applied to one or more individual hazard types. The general structural mitigation groups described are:

1. Resistant construction
2. Building codes and regulatory measures
3. Relocation
4. Structural modification
5. Construction of community shelters
6. Construction of barrier, deflection, or retention systems
7. Detection systems
8. Physical modification
9. Treatment systems
10. Redundancy in life safety infrastructure

5.1.1 Resistant Construction

Clearly, the best way to maximize the resistance of a structure to the forces inflicted by various hazards is to ensure that it is designed for it prior to construction. Through awareness and education, individual, corporate, and government entities can be informed of the hazards that exist and the measures that can be taken to mitigate the risks of the respective hazards, allowing resistant construction to be considered. As a mitigation option, designing hazard resistance into the structure from the start is the most cost-effective option and the option most likely to succeed. Whether or not builders choose to use hazard-resistant design depends upon whether they have access to the financial resources, the technical expertise necessary to correctly engineer the construction, and the material resources required for such measures.

5.1.2 Building Codes and Regulatory Measures

Hazard-resistant construction, as previously explained, is clearly an effective way to reduce vulnerability to select hazards. However, the builders must apply measures for hazard resistant construction for an actual reduction in a population's overall vulnerability. One way that governments can ensure members of the population apply hazard-resistant construction is by creating building codes to guide construction and passing legislation that requires those codes to be followed. Regulatory structures in some form are one of the most widely adopted structural mitigation measures, and are being used by almost every country in the world. With sufficient knowledge about the hazards that are likely to affect a region or a country, engineers can develop building codes that guide builders to ensure that their designs are able to resist the forces of the relevant hazards. Although it is simple in theory, the inherent problems with codes and regulations can drastically decrease their effectiveness.

Building codes ensure that structure designs include resistance to various forms of external pressure. Each hazard emits an unique set of external pressure on the structures, such as:

1. Lateral and/or vertical shaking (earthquakes)
2. Lateral and/or uplift load pressure (severe storms, cyclonic storms, tornadoes, windstorms)
3. Extreme heat (structure fires, wildland fires, forest fires)
4. Roof loading (hailstorms, snowstorms, ash falls)
5. Hydrological pressure (floods, storm surge)

When properly applied, building codes offer a great deal of protection from a wide range of hazards. They are a primary reason for the drastic drop in the number of earthquake deaths in the developing world in the last century. They are so effective because they completely integrate protection measures into the structure from the design phase onward, rather than applying the measures after construction.

5.1.3 Relocation

Occasionally, the most sensible way to protect a structure or people from a hazard is to relocate it or them away from the hazard. Homes and other structures may be disassembled and demolished. Although destroying the original structure and rebuilding it elsewhere is often less expensive and technically more feasible, in certain circumstances such actions are either impossible or undesirable. For example, the structure in question may be a cultural heritage site that cannot be replaced.

5.1.4 Structural Modification

Scientific progress and ongoing research continually provide new information about hazards. This new information can reveal that structures in identified risk zones are not designed to resist the forces of a likely hazard. There are three treatment options for these structures. The first is to do nothing. Second, the structure may be demolished and rebuilt to accommodate the new hazard information. Third, often the most appropriate action, is to modify the structure such that it resists the anticipated external forces. This action is often referred to as retrofitting. About 5% of the total housing stock can be replaced each year with the help of the corporation and the existing building groups. How the retrofit affects the structure depends on the hazard risk that it is being treated for. Examples of hazards and their retrofits include:

- **Earthquakes** Sheer walls, removal of cripple walls, foundation anchor bolts, frame anchor connections, floor framing, chimney reinforcement, base isolation systems, external frames, removal of roof weight, soft-storey reinforcement
- **Wildfire** Replacement of external materials, including decks, gutters, downspouts, panelling, doors, window frames, and roof shingles, with those that are fire-resistant
- **Hail** Increase roof slope, strengthen roof materials and strengthen load-carrying capacity of flat or shallow-angle roofs
- **Lightning** Electrical grounding of the house with lightning rods or other devices
- **Extreme heat** Air-conditioning systems

5.1.5 Construction of Community Shelters

The lives of community residents can be protected from the adverse consequences of a disaster through the construction of shelters designed to withstand a certain type or range of hazard consequences. Some of the communities have existing parking lots which can be converted to emergency shelter with slight modifications. Shelters are usually constructed when it is either unlikely or unrealistic for all or a majority of the community members to be able to protect themselves from the hazard in their homes or elsewhere. Two systems must be in place for shelters to work. First, there must be an effective early warning system that would enable residents to have enough time to travel to the shelter before the hazard event. This immediately rules out several hazards for which warning is impossible or unlikely, such as earthquakes or landslides. Second, there must be a public education campaign that both raises awareness of the existence of the shelter and teaches residents on how to recognize when they should travel to the shelter.

5.1.6 Construction of Barrier, Deflection, or Retention Systems

The forces that many hazards exert upon man and the built environment can be controlled through specifically engineered structures. These structures fall under three main categories: barriers, deflection systems, and retention systems. Barriers are designed to stop a physical force dead in its tracks and acts as blocking devices. Their job is to absorb the impact of whatever force is being exerted. Barrier walls can be made of natural materials, such as trees, bushes, or even existing soil, or they can be constructed out of foreign materials, such as stone, concrete, wood, or metal. Depending upon the hazard type, barriers may be built on just one side of a structure, or may completely surround it. Examples of barriers and the hazards they are designed to protect against include:

- Natural or synthetic wind and particle movement barriers (strong seasonal winds, sand drift, dune movement, beach erosion, snow drift)
- Defensible spaces (wildfires, forest fires)
- Mass movement protection walls (landslides, mudslides, rockslides, avalanches)
- Security fences, checkpoints (terrorism, civil disturbances)
- HAZMAT (hazardous material) linings - for sewerage treatment plants, solid waste dumps, etc. (ground contamination)

Deflection systems are designed to divert the physical force of a hazard, allowing it to change course so that a structure situated in its original path escapes harm. Like barriers, deflection systems may be constructed from a wide range of materials, both natural and manmade. Examples of deflection systems and the hazards they are designed to protect against include:

- Avalanche bridges (snow avalanches)
- Chutes (landslides, mudflows, lahars, rockslides)
- Diversion trenches, channels, canals, and spillways
- Retention systems are designed to contain a hazard, preventing its destructive forces from ever being released. These structures generally seek to increase the threshold to which hazards are physically maintained. Examples include:
- Landslide walls (masonry, concrete, rock cage, crib walls, bin walls, and buttress walls)
- Slope stabilization covers (concrete, netting, wire mesh) vegetation landslides, mudflows, rockfalls;

Detection systems are designed to recognize a hazard that might not otherwise be perceptible to humans. They have applications for natural, technological, and intentional hazards. As more funding is dedicated to the research and development of detection systems, their ability to prevent disasters or warn of hazard consequences before disaster strikes increases. With natural disasters, detection systems are primarily used to save lives. With technological and intentional hazards, however, it may be possible to prevent an attack, explosion, fire, accident, or other damaging events. Examples of detection systems are - imaging satellites (wildfires, landslides, avalanches, fire risk, terrorism, virtually all possible hazards in Shimla).

5.2 Non-Structural Mitigation

Non-structural mitigation, as defined previously, generally involves a reduction in the likelihood or consequence of risk through modifications in human behaviour or natural processes, without requiring the use of engineered structures. Non-structural mitigation techniques are often considered mechanisms where "man adapts to nature." They tend to be less costly and fairly easy for communities with limited financial or technological resources to implement. The following section describes several of the various categories into which non-structural mitigation measures may be grouped, and provides several examples for each:

- Regulatory measures
- Community awareness and education programs
- Non-structural physical modifications
- Environmental control
- Behavioural modification

5.2.1 Regulatory Measures

Regulatory measures limit hazard risk by legally dictating human actions. Regulations can be applied to several facets of societal and individual life, and are used when it is determined that such action is required for the common good of the society. Although the use of regulatory measures is universal, compliance is a widespread problem because the cost of enforcement can be prohibitive and inspectors may be untrained, ineffective, or susceptible to bribes.

Examples of regulatory mitigation measures include:

- **Land use management (zoning)**: This refers to the legally imposed restrictions on how land may be used. It may apply to specific geographic designations, such as coastal zone management, hillside or slope management, floodplain development restrictions, or microclimatic siting of structures (such as placing structures only on the leeward side of a hill).

- **Open space preservation (green spaces)**: This practice attempts to limit the settlement or activities of people in areas that are known to be at high risk from one or more hazards.

- **Protective resource preservation**: In some situations, a tract of land is not at risk from a hazard, but a new hazard will be created by disturbing that land. Examples include protecting forests that serve to block wind and wetlands preservation.

- **Denial of services to high-risk areas**: When squatter and informal settlements come up on high-risk land despite the existence of preventive regulatory measures, it is possible to discourage growth and reverse settlement trends by ensuring that services such as electricity, running water, and communications do not reach the unsafe settlement. This measure is only acceptable when performed in conjunction with a project that seeks to offer alternative, safe accommodations for the inhabitants (otherwise, a secondary humanitarian disaster may result).

- **Density control**: By regulating the number of people who may reside in an area of known or estimated risk, it is possible to limit vulnerability and control the amount of resources considered adequate for protection from and respond to that known hazard. Many response mechanisms are overwhelmed because the number of casualties in an affected area is much higher than was anticipated.

- **Building use regulations**: To protect against certain hazards, it is possible to restrict the types of activities that may be performed in a building. These restrictions may apply to people, materials, or activities.

- **Mitigation easements**: Easements are agreements between private individuals or organizations and the government that dictate how a particular tract of land will be used. To ensure risk reduction in certain vulnerable areas, these agreements restrict the private use of land.

- **HAZMAT (hazardous material) manufacture, use, transport, and disposal regulations**: Hazardous materials are a major threat to life and property in all countries. Most governments have developed safety standards and procedures to guide the way that these materials are manufactured and used by businesses and individuals, the mechanisms by which they are transported from place to place, and the methods and devices that contain them.

- **Storm water management regulations**: Storm water runoff can be destructive to the areas where it originates (through erosion), and to the areas where it terminates (through silting), pollution, changes to stream flows, and other effects. Development, especially when large amounts of land are covered with impervious materials like concrete, can drastically increase the amount of runoff by decreasing the holding capacity of the land. Regulations on storm water management, imposed on private and public development projects, help to manage those negative effects, reducing both hazard risk and environmental vulnerability.

- **Environmental protection regulations**: Certain environmental features, such as rivers, streams, lakes, and wetlands, play an important part in reducing the vulnerability of a community or country. Preventing certain behaviours, such as dumping or polluting these features, helps to ensure that these resources continue to offer their risk-reduction benefits.

- **Public disclosure regulations**: Property owners may be required to disclose all known risks, such as flood or earthquake hazard risk, when selling their property. This ensures hazard awareness and increases the chance that purchasers will take appropriate action for those known risks when they begin construction or other activities on that land. Mitigation requirements on loans. Banks and other lending institutions have much at stake when they lend money to developers. Therefore, lenders can apply mitigation requirements or at the very least require that hazard assessment be conducted, and governments can require that such actions be taken by those lending institutions. Such policies limit the building of unsafe projects.

5.2.2 Community Awareness and Education Programs

Community can protect itself from the effects of a hazard if it is first informed that the hazard exists, and then educated about what it can do to limit its risk. Public education programs are considered as both mitigation and preparedness measures. An informed individual who applies appropriate measures to reduce their risk before a disaster occurs has performed mitigation. However, a public that has been trained in response activities has participated in a preparedness activity. Often termed as 'risk communication', projects designed to educate the public may include one or more of the following:

- Awareness of the hazard risk
- Behaviour modification
- Pre disaster risk reduction behaviour
- Pre disaster preparedness behaviour
- Post disaster response behaviour
- Post disaster recovery behaviour
- Warning

Early warning systems inform the public that a hazard risk has reached a threshold requiring certain protective actions. Depending upon the hazard type and the warning system's technological capabilities, the amount of time citizens have, to act, varies. Some warning systems, especially those that apply to technological and intentional hazards, are not able to provide warning until the hazard has already begun to exhibit its damaging behaviour (such as a leak at a chemical production facility, or an accident involving a hazardous materials tanker truck). The UN Platform for the promotion of early warning states that four separate factors are necessary for effective early warning:

- Prior knowledge of the risks faced by the community
- A technical monitoring and warning service for these risks
- The dissemination of understandable warning to those at risk
- Knowledge by people on how to react and the capacity to do so

Warning systems, therefore, are dependent upon hazard identification and analysis, effective detection systems (as described in the section structural mitigation), dissemination of the message, and public education.

5.2.3 Behavioural Modification

Through collective action, a community can alter the behaviour of individuals; resulting in some common risk reduction benefit. Voluntary behaviour modification measures are more difficult to implement than the regulatory measures previously listed, because they usually involve some form of sacrifice. However, through effective public education, behavioural modification is possible. Tax incentives, or subsidies, can help to increase the success of behavioural modification practices. Examples of mitigation measures that involve behavioural modification include:

- **Rationing:** Rationing is often performed prior to and during periods of drought. Because it can be very difficult for governments to limit vital services such as water to citizens, it is up to citizens to limit their individual usage. Electricity rationing is also performed during periods of extreme heat or cold to ensure that electrical climate control systems are able to perform as required.

- **Environmental conservation**: Many practices, in both urban and rural areas, are very destructive to the environment. Once the environmental feature—a water body, a forest, or a hillside—is destroyed, secondary hazardous consequences may appear that could have been avoided. Through proper education and the offering of alternatives, destructive practices can be halted before too much damage is done. Examples of environmental conservation include environmentally friendly farming practices, wood harvesting that does not cause deforestation, and protecting coral reefs from dynamite fishing and other fishing practices.

- Through tax incentives, subsidies, and other financial rewards for safe practices, individuals and businesses can be coaxed into safer practices that reduce overall risk through financial incentives. Examples of schemes that use financial incentives include lower insurance premiums, housing buyout programs to move out of high-risk areas, farm subsidies for allowing land to be used for flood control during emergencies, and environmentally friendly farming practices (no deforestation, responsible grazing practices, flexible farming and cropping).

- **Strengthening of social ties** When a community strengthens its social ties, it is more likely to withstand a hazard's stress better. For many reasons, the largest is the case urbanization, where these social ties break and are not replaced. In Chicago in 1995, a heat wave caused the death of 739 people. It was later determined that weak social structures were primarily to blame for the deaths, which could have been prevented had friends, family, or neighbours checked on the victims.

5.2.4 Risk Transfer, Sharing, and Spreading Systems

Risk transfer, sharing, and spreading are often considered as mitigation measures, although they do absolutely nothing to reduce actual disaster consequences or reduce hazard likelihood. The concept behind these measures is that the financial disaster consequences that do occur are shared by a large group of people, rather than the entire burden falling only on the affected individuals. The result is a calculated average consequence cost, such as an insurance premium.

Insurance, which is the most common mitigation measure in this category, is defined as:
"A promise of compensation for specific potential future losses in exchange for a periodic payment". Insurance is a mechanism by which the financial well-being of an individual, company, or other entities are protected against an incidence of unexpected loss. Insurance can be mandatory (required by law) or optional. Insurance operates through the use of premiums, or payments determined by the insurer. In exchange for premiums, the insurer agrees to pay the policyholder a sum of money (up to an established maximum amount) upon the occurrence of a specifically defined disastrous event.

The majority of insurance policies include a deductible, which can be a fixed amount per loss (e.g., the first INR1,00,000 of a loss), a percentage of the loss (5% of the total loss), or a combination. The insurer pays the remaining amount, up to the limits established in the original contract. In general, the lower (smaller) the deductible associated with a policy, the higher the premiums. Common examples of insurance include automobile insurance, health insurance, disability insurance, life insurance, flood insurance, earthquake insurance, terrorism insurance, and business insurance.

Insurance allows losses to be shared across a wider population. To briefly summarize, insurance works as follows- an auto insurer takes into account all of the policyholders it will be insuring. It then estimates the cost of compensating policyholders for all accidents expected to occur during the time period established in the premiums (usually 6 months to a year.)

The company then divides that cost, adding its administrative costs, across all policyholders. The premiums can be further calculated using information that gives more specific definitions of the risk to certain individuals. Insurance companies make the majority of their profits through investing the premiums collected. To cover losses in case the severity of accidents or disasters is greater than estimated when the policies were created, insurance companies rely on the services of reinsurance companies.

Reinsurance companies insure insurance companies and tend to be internationally based to allow the risk to be spread across even greater geographical area. It is found that two conditions must be satisfied for a risk to be insurable. First, the hazard in question must be identifiable and quantifiable. In other words, the likelihood and consequence factors must be well understood before an insurer can responsibly and accurately set insurance premiums such that they will be able to adequately compensate customers in the event of a disaster.

Second, insurers must be able to set premiums for "each potential customer or class of customers". Common hazards, such as house fires and storm damage, have a wealth of information available upon which insurers may calculate their premiums. For catastrophic but rare events, such as earthquakes, it can be difficult or impossible to estimate with any degree of precision how often events will occur and what damages would result.

5.3 Summary

Structural mitigation measures are those that involve or dictate the necessity for some form of construction, engineering, mechanical changes or improvements aimed at reducing hazard risk likelihood or consequence. Through awareness and education, individual, corporate, and government entities can be informed of the hazards that exist and the measures that can be taken to mitigate the risks of the respective hazards, allowing resistant construction to be considered. Regulatory structures in some form are one of the most widely adopted structural mitigation measures, and are being used by almost every country in the world. Although it is simple in theory, the inherent problems with codes and regulations can drastically decrease their effectiveness. On the other hand, occasionally, the most sensible way to protect a structure or people from a hazard is to relocate it or them away from the hazard. Homes and other structures may be disassembled and demolished. Some of the communities have existing parking lots which can be converted to emergency shelter with slight modifications. Shelters are usually constructed when it is either unlikely or unrealistic for all or a majority of the community members to be able to protect themselves from the hazard in their homes or elsewhere.

The forces that many hazards exert upon man and the built environment can be controlled through specifically engineered structures. These structures fall under three main categories: barriers, deflection systems, and retention systems. Non-structural mitigation techniques are often considered mechanisms where "man adapts to nature." They tend to be less costly and fairly easy for communities with limited financial or technological resources to implement. Public education programs are considered as both mitigation and preparedness measures. An informed individual who applies appropriate measures to reduce their risk before a disaster occurs has performed mitigation. Warning systems however are dependent upon hazard identification and analysis, effective detection systems (as described in the section structural mitigation), dissemination of the message, and public education.

Risk transfer, sharing, and spreading are often considered as mitigation measures, although they do absolutely nothing to reduce actual disaster consequences or reduce hazard likelihood. The concept behind these measures is that the financial disaster consequences that do occur are shared by a large group of people, rather than the entire burden falling only on the affected individuals. The result is a calculated average consequence cost, such as an insurance premium.

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6

Capital Investment Plan

6.1 Assumptions of Capital Investment Plan

6.2 Cost Benefit Analysis

Benefit Assessment
Quantified Benefits
Non-Quantified Benefits
Economic Internal Rate of Return and Net Present Value Analysis

6.3 Overview of Finance - Shimla Municipal Corporation

6.4 Revenue Account

Revenue Receipts
Tax Revenue
Revenue Ependiture

Detailed Capital Investment Plan prepare for the implementation of the mitigation measures identified after risk assessment has been carried out for various hazards. These mitigation measures were categorized into two groups Structural Measures and Non-Structural Measures. Structural mitigation measures generally refer to capital investment on physical constructions or other development works, which include engineering measures, construction of hazard resistant and protective structures and other preventive infrastructure. Non-structural measures include the investments made for awareness generation and education, policies techno-legal systems and practices, training, capacity development etc.

6.1 Assumptions of Capital Investment Plan

1. The cost estimations are indicative at current price without factoring escalations.

2. Total housing stock considered for restoration and retrofitting are 21660 with average size of 100 sq mt. Average cost for restoration and retrofitting estimated to be INR 4800/ sq mt.

3. Estimated electric power cable in Shimla is 80 kms as per current prices INR 50 lakhs per Kms will require for restoration complete systems.

4. Presently there are 15 parking lots in the SMC area in case of emergency these can be used as temporary shelters. Four toilet blocks proposed at each parking lots estimated each block will cost at current prices INR 1.4 lakhs.

5. Extra 10 emergency shelters are required at various locations each will cost INR 2 Crores.

6. Approximately 25 kms of natural drains require revitalisation. Revitalisation of these natural drains will cost nearly INR 2.5 crores.

7. Approximately 45 kms retaining wall require to constructs. Estimated cost for each km of retaining wall INR 25 lakhs.

8. There are approximately 60 structures including heritage and Governmet in Shimla which requires structural modification and retrofitting. Approximately INR 30 Crores will require for these works.

9. Construction of Barrier and Deflection or Retention Systems at 20 locations or points these will cost INR 5 Crores.

10. Community awareness programmes on disaster mitigation will cost nearly INR 20 lakhs each considering 8000 participants@250/ participant.

11. Reforestation requires at 60 hectare land. Estimated cost for reforestation considered here is INR 2 Crores.

Risk assessment puts 13800 housing structures in highly vulnerable category. Subsidised insurance programme against natural disaster will cost INR 69 lakhs per year.

6.2 Cost Benefit Analysis

The basic principle of cost benefit analysis indicates whether a mitigation measures results in an increase of economic welfare, i.e. whether the benefits generated by the proposed mitigation measures exceeds the costs of it. An economic optimisation can be carried out to determine the optimal level of system. The information provided by the cost-benefit analysis and / or the economic optimisation should be considered as a technical advice to the decision- and policy- makers. In the decision making process it should be combined with other types of relevant information.

An important issue in the economic analysis is the estimation of damage. Various types of damage will occur in case of disaster, such as material (direct) and indirect economic damage, cultural and ecological losses and loss of life.

S. No	Mitigation Measures	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22	2022-23	2023-24	2025-26	2026-27
A	Structural Mitigation										
1	Replacement, Restoration and Retrofitting of Housing Stock	104	104	104	104	104	104	104	104	104	104
2	Retrofitting of Electric Power Distribution System	8	8	8	8	8					
3	Construction of Support Infrastructure at Parking Lots	0.07	0.07	0.07							
4	Construction of Emergency Evacuation Shelters	4	4	4	4	4					
5	Revitalisation of Natural Drains	0.5	0.5	0.5	0.5	0.5					
6	Construction of Retaining Walls	2.25	2.25	2.25	2.25	2.25					
7	Structural Modification retrofitting of important buildings	5	5	5	5	5	5				
8	Construction of Barrier, Deflection, or Retention Systems	2	2	1							
	Sub-Total	125.82	125.82	124.82	123.75	123.75	109	104	104	104	104
B	Non-structural Mitigation										
1	Land use Planning & Management (Consultancy Fees)		0.5	0.5							
2	Community Awareness and Education Programs	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
3	Reforestation	0.40	0.40	0.40	0.40	0.40					
4	Building Codes and Regulatory Measures	0.50	0.50	0.50	0.50	0.50					
5	Training Programme for Professionals in Construction Industry		0.25	0.25							
6	Risk Transfer, Sharing, and Spreading	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69
	Sub-Total	1.79	2.54	2.54	1.79	1.79	0.89	0.89	0.89	0.89	0.89
	Grand Total	127.61	128.36	127.36	125.54	125.54	109.89	104.89	104.89	104.89	104.89

Source: TARU Analysis 2015

Table 43: Capital investment plan

Steps in carrying out the economic analysis for coastal projects included the following:

1. Identifying and quantifying (in physical terms) the benefits that result from the investments and the costs of potentially suitable mitigation measures;
2. Valuing the benefits and costs, to the extent feasible, in monetary terms;
3. Estimating the EIRR or economic net present value (NPV) discounted at Economic Opportunity Cost of Capital @ 12 percent by comparing benefits with the costs.

This section deals with the economic analysis of the project in which the benefits are weighed against the investment cost. The economic analysis also presents the EIRR and the net NPV of the subproject.

6.2.1 Benefit Assessment

Benefit Calculation Approach & Methodology

Benefit	Type of Cost	Measurement Technique	Approach Selected
Avoiding Resettlement	Direct Monetary Benefit	Expected value of resettlement cost avoided	Quantitative analysis. Prevailing Government price of land considered. Prevailing standard construction rate of INR 1500/ ft^2 for housing structure.
Protetion of City Infrastruture	Direct Monetary Benefit	Expected value of Infrastructure loss avoided. Various earlier studies conducted in Shimla where referred	Quantitative analysis. Replacement and repair cost of various infrastructure components where considered
Protection of Livelihood	Direct Monetary Benefit	Expected value of livelihood protection estimated through socio-economic survey	Quantitative analysis. Average per capita income and number of persons employed in various sectors considered too arrived on expected value
Protection of Agriculture Trade	Direct Monetary Benefit	Expected value of agriculture trade loss to non-trading activities after disaster	Quantitative analysis

Table 44: Benefit Calculation Approach and Methodology

6.2.2 Quantified Benefits

Benefits accrue principally from the protection of housing and infrastructure from damage and the avoidance of some other associated costs.

1. Avoiding of resettlement costs that may arise if buildings are damaged. Resettlement of family living in highly vulnerable area will cost INR 415.8 Crores in current prices.
2. According to socio-economic survey carried out in September 2015, average cumulative household income of these families is nearly INR 52.53 Crores/ per year.
3. In absence mitigation measures, the city infrastructure will severely damage. Repair of these infrastructures in current present price will cost nearly INR 280 Crores.
4. Natural disaster will cause stopping of trading activities this will have impact on agriculture crops estimated temporary damage will be nearly INR 1.5 Crores.

6.2.3 Non-Quantified Benefits

The mitigation measure has been assessed based on the benefits that are simpler to quantify. As it turns out, these benefits alone are adequate to provide an adequate rate of return. The proposed mitigation measure implementation will also generate additional benefits that are non-quantifiable. The non-quantifiable benefits are:

1. Increase security for people living in high risk area.
2. Improved security for households, farms and infrastructure at risk adjacent to vulnerable areas
3. Indirect favourable impacts on employment and economic activities in general.
4. Long term benefits that may accrue from institutional strengthening and knowledge and skill upgrading in the public and private sectors.

6.2.4 Economic Internal Rate of Return & Net Present Value Analysis

The estimated value of EIRR is 26 percent and the ENPV is positive with INR 15.78 Crores. By considering the values of key economic parameters the proposed project is found to be economically viable.

										INR Crores	
S. No.		Year									
		2016-17	2017-18	2018-19	2019-20	2020-21	2021-22	2022-23	2023-24	2025-26	2026-27
A	Benefit										
1	Avoidance of Resettlement	41.58	41.58	41.58	41.58	41.58	41.58	41.58	41.58	41.58	41.58
2	Protection of Livelihood	52.53	52.53	52.53	52.53	52.53	52.53	52.53	52.53	52.53	52.53
3	Protection of Infrastructure	28	28	28	28	28	28	28	28	28	28
4	Protection of Loss of Agriculture Crop	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
	Total Benefit	122.26	122.26	122.26	122.26	122.26	122.26	122.26	122.26	122.26	122.26
B	Cost										
1	Cost	127.61	128.36	127.36	125.54	125.54	109.89	104.89	104.89	104.89	104.89
	Cost	127.61	128.36	127.36	125.54	125.54	109.89	104.89	104.89	104.89	104.89
		-5.35	-6.10	-5.10	-3.28	-3.28	12.37	17.37	17.37	17.37	17.37
	EIRR	26%									
	ENPV (In Crores)	15.78									

Table 45: Cost Benefit Analysis

6.3 Overview of Finance – Shimla Municipal Corporation

The total revenues of SMC increased from Rs. 37.71 crores in FY 2008-09 to Rs. 59.15 crores in FY 2012-13. The compounded annual growth rate (CAGR) in revenues during this period was 11.9%. The total expenditure increased from Rs. 41.44 crores to Rs. 71.34 crores over the same period, implying a CAGR of 14.5%. The corporation's revenue account has been in a deficit since the past five years, and the overall surplus is on the account of capital surplus. SMC has not even been able to meet its expenditure. In fact, some times, to pay the salaries of the employees, it had to withdraw money from the fixed deposits of Provided Fund of the employees.

Particulars	2008-09	2009-10	2010-11	2011-12	2012-13	CAGR
	In Crores					
Revenue Account						
Income	37.71	35.56	41.33	54.52	59.15	11.9
Expenditure	41.44	54.27	53.66	65.61	71.34	14.5
Surplus/ (Deficit)	-3.73	-18.71	-12.33	-11.09	-12.19	

Table 46: Statement of Revenue and Expenditure

6.4 Revenue Account

6.4.1 Revenue Receipts

The revenue receipts increased from Rs. 37.71 crores in FY 2008-09 to Rs. 59.15 crores in FY 2012-13, thus showing a CAGR of 11.9%. The own sources (tax and user charges and fees) of revenue over the review period accounted for 51% of the total revenue receipts. SMC receives compensation in lieu of abolition of octroi, from the state government. Tax revenues are in the form of property tax.

Fee and user charges collected by SMC are towards supply of water, parking fee, revenues from advertisement, compounding fee, and other miscellaneous fee. Collection of fees and user charges has shown annual increase of 19.3% from 2008-09 to 2012-13.

Particulars	2008-09	2009-10	2010-11	2011-12	2012-13	CAGR
	In Crores					
Tax Revenue	6.54	7.43	8.33	9.78	10.33	12.1
Fees & User Charges	8.88	10.29	11.41	13.77	18.02	19.3
Rental from Municipal Properties	1.92	2.64	1.90	2.21	2.28	4.3
Assigned Revenue	10.35	10.41	11.35	12.84	15.38	10.4
Revenue Grants and Contribution	7.45	3.29	6.94	14.03	11.08	10.4
Others	2.54	1.47	1.37	1.86	2.04	-5.3
Total	**37.71**	**35.56**	**41.33**	**54.52**	**59.15**	**11.9**

Table 47: Statement of Revenue

6.4.2 Tax Revenue

The third largest component of the revenue income of the corporation is the tax revenue, which increased from Rs. 6.54 crores in FY 2008-09 to Rs. 10.33 crores in FY 2012-13, showing a CAGR of 12.1%. Property tax from commercial increased from Rs. 1.7 crores in FY 2008-09 to Rs. 5.57 crores in FY 2012-13. Other important element of tax revenues is the sewerage tax, which increased from Rs. 0.5 crore in FY 2008-09 to Rs. 0.8 Crore in FY 2012-13, thus showing a CAGR of 12%. As per the HP Municipal Corporation Act, 1994, the sewerage tax is levied on the commercial properties only.

Particulars	2008-09	2009-10	2010-11	2011-12	2012-13	CAGR
	In Crores					
Property Tax – Resdential	4.16	1.76	2.65	2.42	3	-7.8
Property Tax – Commercial	1.70	4.92	4.54	6.03	5.57	34.5
Property Tax – Land	0.68	0.10	0.37	0.51	0.81	4.4
Water Tax	0.04	0.04	0.04	0.07	0.02	-15.9
Sewerage Tax	0.55	0.61	0.73	0.78	0.87	12.1
Vehicle Tax	0.008	0.007	0	0	0	0
Tax on Animals	0.01	0.03	0	0	0	0
Show Tax	0.47	0.17z	0.16	0.1	0.02	0
Total Tax Revenue	**6.54**	**7.43**	**8.33**	**9.78**	**10.33**	**12.1**

Table 48: Tax Revenue

6.4.3 Revenue Expenditure

The establishment expenditure forms more than 52% of the total expenditure of the Corporation. The Act specifies that the establishment expenditure shall not exceed 1/3rd of the total expenditure of the Corporation.

The O&M expenditure is the second largest contributor to the revenue expenditure of the Corporation. It increased from Rs. 19.22 Crores in FY 2008-09 to Rs. 31.09 Crores in FY 2012-13, thus showing a CAGR of 12.7%. The major components of the O&M expenditure have been the expenditure on bulk water purchase (40%), roads and bridges (17%), electricity consumption for street lights (13%), and power and fuel expense (for pumping) (8%).

Particulars	2008-09	2009-10	2010-11	2011-12	2012-13	CAGR
	In Crores					
Establishment Expenditure	21.29	25.13	27.81	33.42	37.48	15.1
Administrative Expenditure	0.84	1	0.85	1.93	2.31	28.7
Operations & Maintenance	19.22	28.11	24.95	29.45	31.09	12.7
Interest & Finance Charges	0.40	0.06	0.02	0.78	0.24	-11
Others	0	0	0.03	0.03	0.22	0
Total	**41.44**	**54.27**	**53.66**	**65.61**	**71.34**	

Table 49: Statement of Expenditure

6.5 Summary

Capital Investment Plan refers to the planning which was done for two types of mitigation measures separately, ie- structural and non-structural. Structural mitigation measures generally refer to capital investment on physical constructions or other development works, which include engineering measures, construction of hazard resistant and protective structures and other preventive infrastructure. Non-structural measures on the other hand, includes the investments made for awareness generation and education, policies techno-legal systems and practices, training, capacity development etc. However, Capital Investment Plan has been developed keeping in mind, certain assumptions such as- cost estimation rate, estimated infrastructural and basic amenities that need to be restored in Shimla, etc.

7

Institutional Capacity Assessment

7.1. Definition: Capacity

7.2. Capacity Assessment Framework for the Study

7.3. Conduct of Capacity Assessment

7.4 Analysis
- Overall Framework
- Description of key indicators
- List of Participants

7.5. Conduct of Capacity Assessment

7.1 Definition: Capacity

Capacity is defined as "the ability of individuals, organizations, organizational units and/ or systems to perform functions effectively and in a sustainable manner". The United Nations Office for Disaster Risk Reduction (UNISDR) views capacity (Terminology on Disaster Risk Reduction (DRR)) as the combination of all the strengths, attributes and resources available within a community, society or organization that can be used to achieve agreed goals. Capacity may include infrastructure and physical means, institutions, societal coping abilities, as well as human knowledge, skills and collective attributes such as social relationships, leadership and management. Capacity may also be described as capability. Capacity assessment is a term for the process by which the capacity of a group is reviewed against desired goals, and the capacity gaps are identified for further action.

7.2 Capacity Assessment Framework for the Study

Capacity assessment has been done to assess and evaluate various dimensions of capacity within the broader institutional system as well as assess the capacity of specific units and individual / community within the system. The study aimed to determine desired capacity (capacity needs) and assess existing capacities (capacity assets). The assessment has helped analyse the gap between what is desired and what exists. The assessment framework was used to design solution if the desired capacities are defined. A further detailed assessment through stakeholder consultation was undertaken to formulate a capacity development response and establish capacity development priorities (long-term strategic initiatives and quick impact initiatives).

The assessment undertaken in this study helped establish capacity baselines for measuring, monitoring and evaluating progress in capacity development. The results of this assessment has served as a catalyst for action, confirm and list priorities for action, offer platform for dialogue among stakeholders, provide insight to operational hurdles; and build support for a common agenda. The conduct of the assessment has been based on the discussions that were held with the concerned agencies/individuals and was further documented in select areas for mainstreaming disaster risk concerns in city's functioning and development. The assessment is not an audit and is not an individual institutions performance measure. The assessment is meant to provide basis for confirmation and consensus.

Capacities to reduce the risk of geological and hydro meteorological hazards lie both within institutions and in the relationships across institutions and sectors. These capacities arise from the relations that are defined through the roles and responsibilities and rules of engagement, and sometimes they are defined in the operation plans of the institutions, City Disaster Management Plan Shimla 2012 (City Disaster Management Cell, Municipal Corporation Shimla, prepared under the GoI-UNDP Urban Risk Reduction Project 2009-2012), or through the ongoing practices which are not documented.

7.3 Conduct of Capacity Assessment

Capacity is defined as "the ability of individuals, organizations, organizational units and/ or systems to perform functions effectively and in a sustainable manner". The United Nations Office for Disaster Risk Reduction (UNISDR) views capacity (Terminology on Disaster Risk Reduction (DRR)) as the combination of all the strengths, attributes and resou The scope reviewed relevant core issues and capacities pertaining to activities within different phases of the disaster management cycle – mitigation (well before), preparedness (before), emergency (during) and rehabilitation (after). The focus was to do a quick mapping of key challenges and priorities. The assessment was conducted at the level of the focus group/individuals from local government as a whole, a specific sector (urban services, emergency management, search and rescue, city development), administrative unit (city administration), communities at risk, single organization/subject experts. It was conducted in two stages:

First stage of assessment was mainly focussed on the discussions held with select focus group/individuals (analyse the gaps). One-to-one discussions were conducted in this stage to gather qualitative information. Refer to Annex A: Interview Template: Assessing institutional capacities for Disaster Risk Management / Disaster Risk Reduction. The list of institutions/individuals interviewed for the first stage and summary of key observations/recommendations is provided in Annex C.

Second stage was conducted through stakeholder consultation process, wherein results of risk and vulnerability of Shimla was produced in the form of maps and other products. The key objective was to benchmark the progress on integration of risk reduction into critical services (energy, water and sanitation, transport), preparedness, emergency response and recovery; mainstreaming of disaster risk reduction into development planning; and capacities for mainstreaming disaster risk reduction. This stage helped generate qualitative ranking of the capacity at the city level. Stakeholders were asked to score the indicators to determine the level of attainment. This scoring was not limited to their perspective or the functioning of their respective institution, but relates closely to the overall status of the city. These scores have been used as proxy to determine the level of desired capacity against the level of existing capacity. Refer to Annex B: Description of indicators and ranking tool to assess mainstreaming of risk reduction at the city level. The qualitative and quantitative response was referred to formulate the capacity development response.

7.4 Analysis: Key gaps and potential areas for intervention

7.4.1 Overall Framework

Key thematic pillars of city level action for Disaster Risk Management

- Mitigation
- Preparedness
- Response
- Recovery

Keysectors for assessing capacity towards mainstreaming Climate Change and DRR concerns

- **Legal and Institutional framework for CC and DRR**
  - 1. Effectiveness of legislative framework for addressing CC and DRR
  - 2. Effectiveness of institutional arrangements for addressing CC and DRR
- **CC and DRR Awareness and Capacity Building**
  - 3. Capacity of various institutions within city and implementation of training capacity building programs.
  - 4. Risk communication, advocacy, public awareness and continued education
- **Responsiveness of critical infrastructure and basic services**
  - 5. Responsiveness of critical infrastructure (healthcare, emergency services, communication and electricity.
  - 6. Responsiveness of basic services (water supply, drainage, transportation and food supply)
- **Disaster preparedness and hazard specific disaster responce**
  - 7. Caapacity of institutions to undertake pre-disaster and post-disaster activities .
  - 8. Resource availability for undertaking preparedeness activities and staging response.
- **Risk mitigation in city planning and infrastructure development**
  - 9. Risk and impact assessment at sector level, investment decisions to mitigate risks.
  - 10. Implementation of risk reduction measures in urban planning, urban development, redevelopment, rejuvination scheme.

Description of assessment indicators and ranking tool to access mainstreaming of risk reduction at the city level

7.4.2 Description of Key Assessment Indicators

Sectors	Assessment Indicators	Key Characteristics
Legal and institutional framework for Climate Change & DRR	Effectiveness of legislative framework for addressing climate change & DRR	Act, regulations and ordinances DRR arrangements Departmental activities and accountability Resource allocation (human and financial)
	Effectiveness of institutional arrangements for addressing CC & DRRz	Disaster management plan addressing CC and DRR Organization structure and defined roles and responsibilities Partnership arrangements (Internally with departments and sectors) for support functions Partnership arrangements with private sector and civil society Monitoring and updation of plan
CC & DRR awareness and capacity building	Capacity of various institutions within city and implementation of training and capacity building programmes on CC & DRR	Knowledge gap identification in the subject of CC and DRR Institutional commitment towards building of core human resources to address CC and DRR
	Risk communication, advocacy, public awareness and continued education	Risk communication strategy Participation in IEC development and outreach Commitment to raising public awareness and education programmes through engagement with all key stakeholders Use of media tools to disseminate information Media relations to facilitate dialogue and effectiveness of action
Responsiveness of critical infrastructure and basic services	Responsiveness / Resilience of critical infrastructure	Resilience of emergency services to undertake operations during emergency situations Resilience of health care services during and post disaster situations Resilience of communication systems
	Responsiveness / Resilience of basic servicesz	Resilience of electricity services Resilience of water supply systems Resilience of drainage systems Resilience of transportation systems Contingency planning for delivery of essential services (supply of food, logistics support, resource management)

Disaster preparedness and climate-induced disaster response	Capacity of institutions to undertake pre-disaster and post-disaster activities	Functioning of City Emergency Operations Centre (EOC) and effective coordination
		Functioning of departments and sectors as outlined in the Standard Operating Procedures (SOP's)
		Departmental coordination mechanism and tested through simulation exercises or mock drills
		Multi-agency response mechanism
		Recovery plan for each sector / department and restoration of services within a stipulated time frame
		Risk assessment of systems analysed and steps taken towards staging effective response and recovery
	Resource availability for undertaking preparedness activities and staging response, department level contingency plan	Institution level contingency plan for various risk scenarios
		Ability to deploy resource (human and financial) to address disaster risk management needs
		Budget line (fixed) at the institution level to respond to emergencies
Risk Mitigation in city planning and infrastructure development	Risk and impact assessment at sector level, investment decisions on mitigation	Institutional level awareness of CC & hydro meteorological risk, geophysical risk (earthquake and landslide)
		Impact assessment studies to determine losses
		Investment decisions towards loss minimization
		Business continuity management (core function operation)
	Implementation of risk reduction measures in urban planning, urban development, redevelopment / rejuvenation / upgradation scheme	Risk sensitive planning for city development / redevelopment areas
		Mainstreaming disaster risk reduction in programmes and projects
		Capital investment in disaster risk reduction
		Strengthening of city infrastructure to cope/adapt to future risks and urbanization

The measurement/effectiveness of these indicators at the city level is done through a ranking exercise for each of the ten listed indicators. The performance target is graded on a scale of five and it corresponds to the various attainment level as described below:

Level 1 – Very Low	Negative territory
Level 2 – Low	
Level 3 – Moderate	Transition between negative and positive territory
Level 4 – High	Positive territory
Level 5 – Very High	

Each indicator is guided through a set of questions that can guide the individual to select a particular attainment level. The details are given in subsequent section

Assessment Indicator	**Effectiveness of legislative framework for addressing CC & DRR**
Stregths	The city has developed a City Disaster Management (City DM) Plan (2012) for all major hazards
Gaps	The City Disaster Management Plan (2012) has not taken the route of implementation and monitoring the actions taken by various departments / stake-holders
Potential Areas for Intervention	Passing of city resolution/ ordinance to address and mainstream geophysical, hydro-meteorological and climate change risk in the overall city development and sector/department operations (especially around critical/urban services). Resolution/Ordinance to also highlight the required legislative framework which can aid operational process by bringing in all key departments at the city level. State department linkages also to be established across key sectors for risk management (mitigation, preparedness, response and recovery) Local government to draft a city wide policy to address integration of DRR in all developmental activities
Assessment Indicator	**Effectiveness of institutional arrangements for addressing CC & DRR**
Stregths	The City Disaster Management Plan (2012) outlines the roles and responsibilities of the institutions to address key hazards
Gaps	The City Disaster Management Plan (2012) hasn't been updated for over three years and it has to be made more relevant with respect to the risk profile of the city. The existing plan lacks serious attention in creation of the institutional arrangements that encompasses all activities in the various phases of disaster risk management There is no active partnership with civil society organizations (CSOs) so as to assist response and recovery efforts in case of a severe event. There is an overall lack of clarity at thelevel of local government to establish institutional mechanism for disaster risk management/ reduction. This is evident at the level of city planning, sanctioning of buildings in risk prone areas, and no mechanism for checking structural integrity of buildings for seismic/ landslide and fire risk Since the City Disaster Plan has been in effect from 2012, the effectiveness of the institutional arrangements for DRR has not been evaluated at the city level
Potential Areas for Intervention	Local Government to review existing arrangements and create an institutional mechanism/ framework which can aid comprehensive planning for disaster management at the city level, establish linkages with the state level for effective risk governance. Prepare comprehensive city wide disaster management plan encompassing: All hazards approach (including CC) Institutional framework for all hazards approach Encompass all phases of the disaster management cycle and required institutional arrangements Establish links with the technical institutions, corporate sector and civil society organizations Fix the roles and responsibilities of all agencies and develop Standard Operating Procedures (SOPs) and interoperability mechanism Build response capability by integrating and empowering / training the local communities and citizens (basic first-aid, search and rescue, stabilization of weak slopes and shoring of buildings). Create a dedicated department/cell with sufficient human resource to address disaster risk management function and establish linkages with other line departments for effective streamlining of DRR in development
Assessment Indicator	**Capacity of various institutions within city and implementation of training and capacity building programmes**
Stregths	The institutions in the city has capable human resources at the department/sector level to deliver key department functions

Gaps	DRR is not the key agenda/ focus in department functions There is a lack of understanding / knowledge on DRR and very limited know-how on integration of CC/DRR in the planning and operational function of departments The departments have limited resources to undertake sensitization/ training programmes.
Potential Areas for Intervention	There is a need for developing a comprehensive / long-term training and capacity building programme on CC and DRR for urban local body, line departments and key city stakeholders Department wise 'tailor-made' DRR literacy programmes need to be developed for effective mainstreaming of CC and DRR in department roles and functions Community outreach programme on DRR literacy should be undertaken to fast track risk management /climate change adaptation at the city, neighbourhood and household level Source of additional funding has to be identified by the local government to implement the training and capacity building plan addressing CC and DRR Build linkages/network with CSOs to address risk management concerns
Assessment Indicator	**Risk communication, advocacy, public awareness and continued education**
Stregths	SMC has undertaken programmes on educating general people on basics of disaster management. Select NGO's have also initiated the process of developing IEC material and organizing meetings and trainings for citizens of Shimla.
Gaps	There is no strategy as on date to communicate risk through a designated agency/department at the city level The city as a whole falls short in terms of IEC development on issues of risk and its management The city lacks a strategy on awareness campaign for CC and DRR
Potential Areas for Intervention	Development of long-term IEC campaign/plan to sensitize and raise the awareness of citizens and stakeholder on prevalent hazards, impacts and solutions Development of IEC material which identifies solutions across the state (household, community /neighbourhood and city level) Dissemination of information through use of modern communication technology (audio/video/messages), print and through local cable channels. Launch of comprehensive outreach programme by involving government and private schools across the city
Assessment Indicator	**Responsiveness of Critical Infrastructure** **(Emergency services, Healthcare services, Communications and Electricity)**
Stregths	The City Disaster Management Plan (2012) highlights the roles and responsibilities of key departments
Gaps	The technical/equipment resources with the Fire Services Department/ Civil Defence and Home Guards indicate lack of preparedness for a severe earthquake event in the city. The fire and emergency services lack portable equipments and vehicles to assist search and rescue operations in case of multiple building collapse The City Emergency Operations Centre (EOC), located at SMC lack technical manpower and technology back-up to map and understand threats on real-time basis. The existing mechanism is dependent on the emergency call service to nodal departments and doesn't provide / capture the space and time dimensions of the threat phenomenon Sectors namely health, communications and electricity have not undertaken risk assessment of their facilities for prevailing hazards

Potential Areas for Intervention	Department wise contingency plan preparation for various event scenarios Service restoration and business continuity plan Procurement of portable emergency equipments and smaller emergency vehicles to assist hill conditions Training and capacity building to build resilience in all aspects of service delivery mechanisms Incorporate technology options for decision making Harden / retrofit / strengthen critical infrastructure to withstand extreme events, backed by adequate financial support
Assessment Indicator	**Responsiveness of Basic Services** **(Water supply, Drainage, Transportation, Food supply)**
Stregths	The City Disaster Management Plan (2012) highlights the roles and responsibilities of key departments Presence of reliable infrastructure across the city, expansion plans / service outreach plans are implemented through various ongoing schemes
Gaps	Impact assessment of hazard risks have not been undertaken for basic services Existing City Disaster Management Plan (2012) doesn't identify the severity of impact on basic services. Expansion plan / rehabilitation plan for services doesn't take into account the existing hazard risks or threats
Potential Areas for Intervention	Department wise contingency plan preparation for various event scenarios Service restoration and business continuity plan Training and capacity building to build resilience in all aspects of service delivery mechanisms Incorporate technology options for decision making in normal operations (services monitoring) which can be scaled to monitor during extreme events Harden / retrofit / strengthen critical infrastructure to withstand extreme events, backed by adequate financial support
Assessment Indicator	**Capacity of institutions to undertake pre-disaster and post-disaster activities (response and recovery)**
Stregths	Chapter 10 of the City Disaster Management Plan (2012) highlights in brief the institutions responsible for recovery efforts.
Gaps	The local government is yet to put across a comprehensive multi-agency response mechanism for various hazard events Department wise pre-disaster and post-disaster (response and recovery) functions are covered in the SOPs section of the City Disaster Management Plan (2012). The SOPs can be further tailored to specific hazard risk No specific understanding at the city level institutions to undertake post disaster needs assessment study No formal process to test the plans through conduct of table-top exercises and simulations
Potential Areas for Intervention	Develop comprehensive plan for disaster management (encompassing preparedness and response/recovery needs). Plans to be tested through conduct of table-top exercises and simulations Institutions/departments shall identify specific teams to address / cater to pre-disaster and post-disaster issues and manage effective coordination through formulation of SOPs Sectors / departments shall develop recovery plan thereby highlighting the resources needed for restoration of services within a stipulated time-frame

Assessment Indicator	Resource availability (human, technical and financial) for undertaking preparedness activities and staging response, department level contingency plan
Stregths	City level departments have identified human resources and deployment of technical resources for addressing this. The local government has the ability to seek assistance form the state for additional resources
Gaps	There are no departmental contingency plans to further back the City DM Plan (2012) Although the City DM Plan (2012) highlights the SOPs for frontline agencies /departments (critical and basic services), there is no clarity on this subject at the department's functional level Lack of human resources with understanding on the subject of CC and DRR, disaster risk management There is no definite financial resource available for developing, testing and evaluating contingency plan across the departments
Potential Areas for Intervention	Develop department wise contingency plan for possible risk scenarios. Plans should outline the roles and responsibilities of individual agency along with SOPs and interoperable mechanisms Train a cadre of core professionals from all key agencies/departments in disaster risk management City to allocate sufficient financial resources (in the form of annual budget at the local government level) for disaster risk management

Assessment Indicator	Risk and impact assessment at sector level, investment decisions to mitigate risks
Stregths	Several assessment studies and projects on climate resilience is implemented in the city by development partners
Gaps	Existing infrastructure is deficient relative to take action needed for hazard (especially earthquake and landslide) Lack of fund for maintenance and seismic strengthening of city's core infrastructure There is a lack of political will to prioritize safety agenda
Potential Areas for Intervention	Design new infrastructure by taking into consideration the prevalent / future risks and their possible impacts Create operations and maintenance fund / mitigation fund at the city level to strengthen/retrofit existing infrastructure in a phased manner

Assessment Indicator	Implementation of risk reduction measures in urban planning, urban development, redevelopment / rejuvenation / upgradation scheme (shelter, basic services)
Stregths	Risk reduction (mitigation) has been highlighted in the City Disaster Management Plan (2012)
Gaps	Existing plans are insufficient to tackle the issues of geophysical and hydro meteorological disasters There is no clear consensus within the sectors/ departments to address geophysical and hydro meteorological disasters in a holistic manner. Coordination among the departments seems to be a bigger challenge The city has a significant stock of weak/unsafe buildings.
Potential Areas for Intervention	The revised/updated City DM Plan should emphasize on development of a comprehensive strategy to deal with geophysical hazards and hydro-meteorological hazards Unsafe building stock/housing units must be replenished with new planned areas and building stock (these areas need to be brought under a special package such as redevelopment/rejuvenation) Provide training to city engineers and planners, development professionals on risk sensitive planning, mainstreaming CC and DRR in development programme/ activities Relocate people residing in areas of high risk by providing safe housing, basic services and livelihood opportunities

7.4.3 List of Participants

Discussions were held with the following individuals / institutions to understand the capacity at the city and ward level

Shri Sandeep Sharma, State Town Planner, Directorate of Town and Country Planning Department

Dr H R Thakur, District Health Officer, Rippon Hospital

Shri Baldev Singh, Commandant Home Guard's Cum Deputy Controller Civil Defence

Shri G C Negi, Additional District Magistrate - I

Shri Viveik Saigal, Community Volunteer/Leader, Summer Hill, Shimla

Shri D D Sharma, DFO, Fire Services Department, Shimla

Shri M L Thakur, SFO, Fire Services Department, Shimla

Dr Sonam G Negi, Health Officer, Municipal Corporation Shimla

Shri Prashant Sirkek, Assistant Commissioner, Municipal Corporation Shimla

7.5 Summary

1. Legislative issues and enforcement

The nodal department has brought out ordinance in regard to construction in hill areas. There is no enforcement mechanism towards safety of buildings in the city of Shimla. Adhoc regularization of buildings is a major hindrance to safety. Shimla Municipal Corporation needs to have robust techno-legal regime backed with professionals who conduct safety checks of buildings and ensures implementation, stoppage of all adhoc approvals/ regularization. Building safety has to be handled by professional team and must not have political influence. Responsibility of building safety must be with the Shimla Municipal Corporation. A large portion of the building stock in the city doesn't meet the requirements of Part IV - Fire and Life Safety (National Building Code). The Fire Department is the competent authority on this subject and more power have to be entrusted on them. Fire Department should be given the responsibility of giving the No Objection Certificate (NOC).

2. Awareness and capacity building

The nodal planning department undertakes sensitization programme on safe development practices. Capacity of the staff at the municipal level on building safety (seismic and other hazards) is low. The planning department staff need further training on incorporation of risk in physical planning (risk sensitive land use planning, redevelopment planning after disasters). Capacity building of built environment professionals (Architects, Engineers, Planners), construction workforce (masons, carpenters, bar benders) and building materials supplier and distributors. There is need to train health professionals in disaster management / emergency care management / mass casualty management – especially in handling of large scale emergencies. Communities have to be trained in basic search and rescue and first aid (create a pool of volunteers at the city/ward level). The city has to practice mock drills on a regular basis and test the current city and department level/sector level plan, incorporate the gaps and continously improve the plan. Public education on hazards and risk need to be communicated (their role in the first 72 hours, emphasis on home preparedness plan).Attempt has been undertaken by the Shimla Municipal Corporation to involve public in disaster management issues.

The programme 'Building Urban Actions for Resilience in Emergencies' (BUARE), a collaborative initiative of Municipal Corporation Shimla, Himachal Pradesh State Disaster management Authority and UNDP India must be continued and established across all the wards in the city. Support may be drawn from development agencies, NGOs and the private sector to steer/expand this initiative.

All departments across the city/district will have to draw quality training on disaster management. Resource institutions and key resource persons will have be arranged for undertaking department wise trainings so as to enhance the level of preparedness and respond to an emergency. In addition mitigations actions have to be initiated at the department level to minimize the damage.

Capacity building of building sector professionals and health sector professionals should be undertaken on priority basis. Training of communities is the key. Programme such as community emergency response team (CERT) / neighbourhood emergency eesponse team (NERT) can be initiated across the city and a pool of volunteers in the city can be always be ready for immediate action in case of an emergency. The idea is also to enhance the capacity of the families across the city to be prepared for a 72 hour survival plan in case of an emergency.

Through the community / neighbourhood programme families can be encouraged to prepare their home disaster management plans. The volunteers will have to be trained in basic first aid, light search and rescue, preparation of survival kit for their homes and urgent non-engineering repairs or even temporary shoring of small destabilized slopes and buildings (of small heights and mainly non-structural elements).

3. Emergency preparedness

Most of city's critical services (water supply, health/medical services, communications, transportation, emergency services including search and rescue) will not withstand moderate to major disaster event. There is no clear plan on back-up mechanisms for failure of existing services and a timely recovery plan. Urgent need to establish measures for mass casualty care. City health contingency plan (in line with state/district health contingency plan) need to be prepared. Service networks within hospitals (electricity, water supply, and communications) may be badly disrupted in case of earthquake.

The emergency plan of hospitals need to incorporated in these scenarios in the plan preparation. Schools in city can undertake school safety and preparedness programme. Himachal Home Guards is currently providing support to select schools on emergency preparedness (tips on evacuation and elementary skills as responders).

Coordination mechanism among departments (state / district / city) need significant improvement. Realistic pre-arrangements have to be defined in terms of action to be initiated for rescue and relief activities. City wide resource inventory has to be prepared on a priority basis and access should be made available to key departments (city database, tools and equipment's, human resources, registered / un-registered volunteers, relief materials, food supplies etc). Given that the city witnesses a large floating population (tourists) it is important that the disaster management plans are developed for hotels / restaurants/ lodges and other small businesses.

Every department should bring out a command mechanism for emergency response as part of their preparedness measures. The department plan should be always at a functional stage (regularly updated) and should have the mechanism for self-activation. Inter- departmental coordination arrangements have to be rolled for planned execution. The buildings in the city are prone to fire hazard. The city must work towards implementing a full scale fire preparedness / prevention plan.

4. Emergency Response

Networking of hospitals and resource planning and management for disaster situations. Securing medical supplies for emergency response (the current supplies will last for approx. 2- 2 ½ months, however the challenge is that the stocks are kept in unsafe buildings and may not be accessible during a seismic event

The availability of staff (medical and paramedical) during a large scale emergency will depend on their availability. There is a need to deploy fully trained Quick Response Team of minimum 15-20 people (day/night shift) drawn from Home Guards and Civil Defence. The current set of tools and equipment's available with the emergency service agencies may not be relevant in the context of Shimla city. There is need to have portable tools and equipment's which can be quickly mobilized for search and rescue operations. The emergency services team will require couple of small vehicles (van type which can navigate the hill roads) loaded with compact tools. Collapse Search and Rescue training (professional course) will have to be provided to Emergency Service Departments in the city. The community members / volunteers can be on light search and rescue with equipment cache.

Civil defence volunteers and other category of volunteers identified across the city will have to be covered under insurance. Resource deployment plan for emergency has to be undertaken / given priority. As city of Shimla falls in high seismic risk zone, liaison arrangements between city-district-state-national and other key resource institutions have to be established in advance.

Public Works Departmwnt (PWD), Health, Irrigation and Public Health (IPH), Fire Department, Civil Defence and Home Guards will be the key responders for an emergency situation in the city of Shimla. These agencies can come together to form a common operation picture/plan for certain risk scenarios and prepare response plans in advance.

There is an urgent need to streamline response plan for the city/district. Line departments across the city do not have preparedness plan for major events. The recovery time / recovery plan for the departments is not developed. Interdependency arrangements / pre-agreements (internal and outside the state) doesn't exist. Escape routes / safe pathways are not demarcated across the city. It is important to take a full exercise in mapping these pathways and keep the routes functional (removing all blockades).

The city's defunct fire hydrant system must be overhauled and put into operational use. A large portion of the building stock in the city is accessible by foot. Considering difficulty in vehicle movement on slopes and difficulty in access, emergency services units will have to deploy resources (human and equipment support) keeping in mind these constraints.

For rapid response to fire emergency, there is a need for more fire tending, equipment cache suitable to hill terrain conditions and more human resources (an additional of 70 fire personnel is required by the Fire Department).

5. Planning and infrastructure development

Commercial interests and regularization are the main impedements to risk mitigation action. There is no prior exposure of planning professionals in preparation of Redevelopment Plan for seismic safety and other hazards. The risk of the built environment is significant and hence a strategy has to be laid down towards physical planning, rejuvenation, which incorporates DRR. Structural strengthening / retrofitting of key lifelines (medical facilities, communications, roads and bridges, urban services – water supply, sanitation, transport, electricity) needs to be done. Revisit city planning / city development from the perspective of risks (geophysical, hydro meteorological) and impacts of CC. The focus of mitigation has been very limited and this need to be looked on priority given the risk. Technical institutions can provide inputs to a range of mitigation options for the city. Specific agreements can be made between the local government institutions and the technical institutions for support. Buildings safety has been ignored for a long time. / regulatory aspects of development control should make mandatory safety rules and compliance as per the National Building Code norms.

8

Discussion and recommendations

Shimla being a hill station, is one of the favourite tourist destinations in India. However, the city cannot only sustain on tourism. Tourism apart from inducing economic activities, also has a negative impact on the city and its resources. To start with, availability of water is a major problem. If the current trend continues, the available water per capita will be further reduced. Already the city depends on water supply from sources which are at a distance from the city limits. Increasing the pressure on the existing water supply systems will worsen the situation. Ground water extraction is also very high within the city limits. Even though several hotels and restaurants are dependent on the ground water, it a rather non-advisable practice for a city like Shimla.

Second problem is parking. During the weekends and holidays, the population of Shimla gets doubled. People from the neighbouring areas like – Solan, Chandigarh, Delhi and Haryana come to Shimla with private vehicles, which almost equals the existing population of the city. At the peak hours, the traffic situation goes from worse to worst, with no land remaining unoccupied. If an earthquake or any other disaster occur at this hour, the consequences will be catastrophic. This city needs to take measures to reduce the number of vehicles on the streets, to ensure that the emergency vehicles, like- ambulances, fire trucks, military vehicles, etc can move and function effectively during emergencies or in case of hospitalization of patients. Third problem is the haphazard construction. Many people are aware of the unsafe conditions of the housing stock within their city but do not take any action to alter the construction quality. Two types of construction qualities have been observed in the city – one, for self-occupying; second, for lending purposes. The quality is apparent in terms of the construction details, material used and also the maintenance. In general, the construction done by the middle income and lower income people is of further inferior quality. Many a times, the buildings are built on installments ie. some part of the building is built at one time while the other floors are constructed at different time periods, leading to weak joints between these floors.

Fourth problem is the lack of engineered building techniques. The general construction labourer available in Shimla (or other parts of the state for that matter) are trained in traditional building construction techniques like dhajji dewari or khat khuni. However, because of non-availability of wood and mud, owners have turned to RCC in recent times. Thus construction workers not being trained in the RCC and brick usage, produce inferior quality of construction. Apart from the above mentioned problems the city is impacted by several hazards, thereby increasing its risk. Some of the measures to reduce the risks were proposed in the earlier section. Here a description of the same is provided.

Replacement, Restoration and Retrofitting of Housing Stock: As the housing stock is very vulnerable, it is proposed that at least 10% of the existing stock be replaced annually. This will ensure that the existing stock is upgraded to safer stock. **Retrofitting of Power Distribution System**: City's existing power distribution system is vulnerable to landslides and earthquakes. So retrofitting the buildings and equipment will enable them to become more resilient.

Construction of Support Infrastructure at Parking Lots: There are about 15 parking lots in various parts of the city. In case of emergency, currently there are no assembly points or rescue shelters within the city. So if basic infrastructure – toilets, water supply, etc. is affected, these parking lots can be converted into emergency shelters.

Construction of Emergency Evacuation Shelters: Wherever parking lots are not available, new evacuation shelters be constructed in order to facilitate the relief and rescue operations

Revitalisation of natural drains: Many of the buildings (both private and public) have come up by disturbing the natural drainage patterns. In those cases, the streams are diverted to other places, causing many of the areas to become vulnerable to landslides. By revitalising the natural drainage, we can make sure that there are no accumulation of water, which gives rise to mass movement.

Construction of retaining walls: Many parts of the roads are already provided with retaining walls. However, the 'weepholes' are blocked either due to siltation or with food wrappers and plastic bottles. Removing these obstacles will help drain out the excess water retained in the soil. Constructing the retaining walls, where they are damaged or were not constructed earlier will help secure the roads from slides and mass movement.

Structural modification retrofitting of important buildings: Many of the government buildings were constructed more than 150 years ago and hence many of them are in physically weak conditions, due to which they may not be able to take the seismic or landslide loads. So retrofitting them will ensure business continuity even in the event of a disaster.

Construction of barrier, deflection, or retention systems: Places where landslide susceptibility is high, constructing the landslide barriers, deflection structures and retention systems will provide adequate safety to the existing housing.

Land use planning & management: In order to identify and delineate hazardous zones, and provide for zoning regulations, a detailed land use planning exercise needs to be carried out. Some basic studies are needed before taking up this exercise, like hazard zonation, seismic micro zonation, landslide susceptible area marking, etc. Based on these studies, land use zoning can be carried out in the safer areas.

Community Awareness and Education Programs: Community awareness is one of the key elements in reducing the risk. Making this document publicly available can create unwanted situation by creating panic among people. However, a proper public participation based awareness generation among the community is needed if the city wants to reduce the risk.

Reforestation: Many of the areas within and outside the city boundaries are being cleared off for building or constructional purposes. These deforestation activities will increase the run off thereby increasing the landslide susceptibility. So proper precautions need to be taken in order to reduce the barren areas.

Building codes and regulatory measures: In a recent move, the Director, Town and Country Planning had modified some of the activities related to building construction. They are:

- Abolition of building inspection committee
- Abolition of 'restricted zone' for construction
- Any architect can approve the building permission
- These activities not only undermines the existing building vulnerability, but also jeopardizes the lives of thousands of people. Building and construction lobby being very active, every marginal area within the city is being built up without considering the consequences of such acts.

Training programme for professionals in construction industry: Separate professional training and certificate programs for the masons, contractors, architects, engineers, construction labourers will help ensure that the hazard and vulnerability information is passed on to the construction workers. At the same time, latest building codes and how to adhere to the same can also be transmitted to the construction professionals.

Risk transfer, sharing, and spreading: Encouraging each and every household to insure their property can help the city by reducing the burden of financial support to be given by either city or the state. If the premium is beyond the financial capacity of the household, various cost sharing mechanisms can be worked out.

Set of recommendations from Director, Town and Country Planning, Divisonal Town Planning Office, Himachal Pradesh are herewith enclosed:

- To stop the construction activity of high raise buildings in Shimla town - especially core area.
- Building code and other regulatory measures shall be adopted by Municipal Corporation and other Authorities in Shimla Town.
- The masons, plumbers, bar-bender and other skilled workers have to be trained for construction of buildings. The skill development programme shall be started

soon.

- Vide notification dated:-13.08.2015 this department has banned the construction activity Sanjauli Dhalli bye pass 15.00m on either side to avoid cutting of steep slopes.
- The Town and Country Planning Department has identified the Sinking and Sliding Zone in the Interim Development Plan in Shimla Town where as Geological Report is required for reconstruction and new construction on vacant plot shall be allowed on the basis of a structural design in consonance with Geological Report from the state Geologist shall be applicable in these Areas.
- All the buildings bye laws of department of Town and Country Planning be followed.
- The natural drainage system shall not be disturbed and minimum 3.00mdistance from nallah and 5.00m from khud has to left as per bye laws.
- Every Planning Permission case in Shimla Planning Area permission cannot be allowed above 45o slope.
- Every Govt. and Semi Govt. building should install a fire hydrant for fire safety.
- The constructions shall be quite away from highest flood level on major rivers in state.
- The Shimla City is already congested and decongestion of old city is most important. The Govt./Authorities shall not allow construction in already congested area. To decongest the city developing of satellite towns needs importance. The Town & Country Planning Dept. has already identified these at Wakanaghat, Ghandal and Fagu.
- Proper monitoring of construction activities especially with reference to structure design, slopes etc. are regularly to be done by authorities.
- The dumping grounds should be identified and later it should be developed as grounds and can be used for disaster events and for parking.
- Alternative spokes has to be developed to ease traffic between cart road and bye pass. The plan stand already submitted.
- All the safety measures has to be adopted in private building also.

8.1 Summary

The city of Shimla, along with having several advantages such as- scenic beauty and famous tourist destination, also suffers from a few serious backlogs. To start with, availability of water is a major problem and increasing the pressure on the existing water supply systems will worsen the situation. During the weekends and holidays, the population of Shimla gets doubled with the people from the neighbouring areas like – Solan, Chandigarh, Delhi and Haryana coming to Shimla with their private vehicles. This city needs to take measures to reduce the number of vehicles on the streets, to ensure that the emergency vehicles, like- ambulances, fire trucks, military vehicles, etc can move and function effectively during emergencies or in case of hospitalization of patients.

Haphazard construction within the city is yet another major problem that needs to be dealt with. Many people are aware of the unsafe conditions of the housing stock within their city but do not take any action to alter the construction quality. Moreover, many a times, the buildings are built on installments ie. some part of the building is built at one time while the other floors are constructed at different time periods, leading to weak joints between these floors. Fourth problem is the lack of engineered building techniques. Some of the recommendations for risk reduction in the city are:

- Replacement, Restoration and Retrofitting of Housing Stock
- Retrofitting of Power Distribution System
- Construction of support infrastructure at parking lots
- Construction of Emergency Evacuation Shelters
- Revitalisation of natural drains
- Construction of retaining walls
- Structural modification retrofitting of important buildings
- Construction of barrier, deflection, or retention systems
- Land use planning & management
- Community Awareness and Education Programs
- Reforestation
- Building codes and regulatory measures
- Training programme for professionals in construction industry
- Risk transfer, sharing, and spreading

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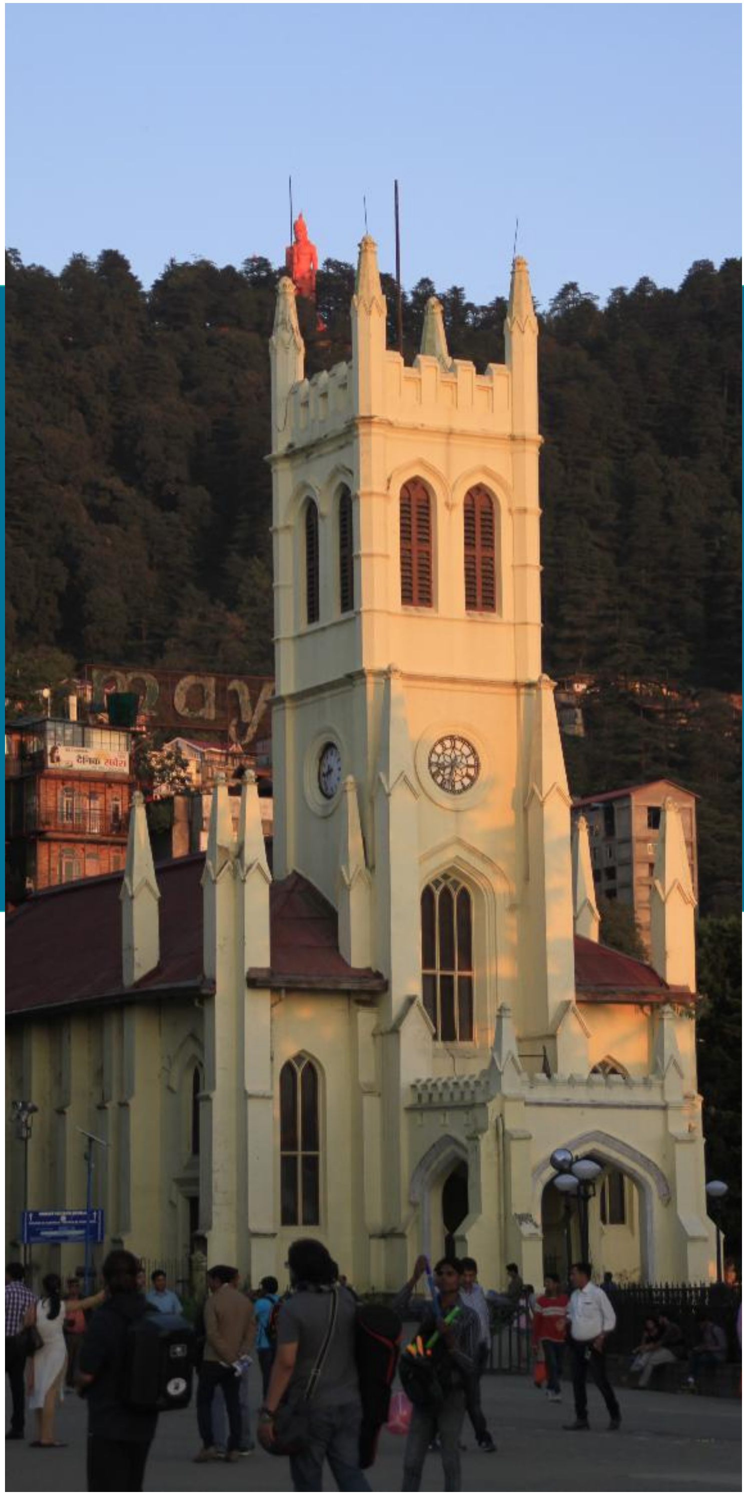

TARU

Taru Leading Edge Pvt. Limited

Corporate Office: D-406, Ganesh Meridian, Opp. Gujarat High Court, S. G. Highway,
Ahmedabad-380060, Gujarat, India.

Regd. Office: M-6, 2nd Floor, Aurobindo Marg, Hauz Khas, New Delhi-110016, India.

Phone: +91-11-26518271, 26518272, Fax: +91-11-41580116
Phone: +91-79-40052401, 40052402, Fax: +91-79-40052400

Website: http://taru.co.in,
Email: info@taru.org