6.1 Discussion:

The National Capital (Delhi) Region of India is exposed to seismic hazard in two scenarios because of its location (i) due to the occurrence of the great earthquake(s) in the central seismic gap of Himalaya and/or (ii) due to the occurrence of the moderate size earthquake(s) within NCR itself. The region is more vulnerable because of its high population density, rapid growth of built environment and old structures. The evaluation of seismic hazard using different approaches is required for the effective hazard mitigation plan. The seismic hazard based on the simulated accelerograms due to moderate/large size earthquakes within NCR has been evaluated in the present thesis. A simple and computationally efficient semi-empirical envelope technique has been used for the simulation of strong ground motions as the more sophisticated techniques like Green’s function technique are difficult to apply in the region. The aptness of the adopted technique has been demonstrated by modelling the empirical accelerograms of the earthquake occurred in NCR.

The accelerograms due to five possible earthquake scenarios have been simulated at bed rock as well as at surface level. The empirical transfer functions have been estimated using waveforms of 23 locally recorded earthquakes for this purpose. The simulated accelerograms can be used for the designing of significant structures whose seismic safety evaluation requires analysis using a complete ground motion time history. In addition to this the attenuation relation, required in the adopted envelope technique, for pga with distance has been identified for the NCR. This relation is useful for the seismic hazard studies of the region. The scenario hazard maps have been prepared by drawing the contours of pga and spectral acceleration values for different periods. The higher pga values estimated at few sites near the probable fault zones are found to be in agreement with those of reported in the literature using different techniques. The seismic exposure of the population of the region has also been estimated. The information available in the scenario hazard maps presented in this thesis is complementary to the information available in probabilistic hazard maps.
The contour maps of response spectrum at various periods are useful for the assessment of the damage potential to various categories of housing and other structures in the region. This information is crucial in the planning of mitigation and disaster management programs.

6.2 Conclusions:

Following conclusions are inferred from the present study:

(i) The site amplification functions have been estimated based on waveforms of 23 locally recorded earthquakes at using the HVSR technique and found that the average value of the site amplification for the frequency band 3.0-10.0 Hz lie in the range 2.0-5.3 for the sites with significant soil cover while the amplification corresponding to the predominant frequency is 2.5-7.5 at most of the sites. But for the sites with less or no sediment cover the amplification ranges from 2.0-3.0 such as at RID etc.

(ii) The maps showing the spatial distribution of the site amplifications at different frequencies corresponding to the natural frequencies of the different storey buildings have been prepared. The amplification for the single storey in NCR is less than 5.0 while for double storey buildings it is of the range 1.0-9.0. This shows that the seismic hazard is significant for single storey and high for two storey buildings.

(iii) The amplification levels for 3-4 storey buildings are found to be comparatively high at Agra and Firozabad and decreases towards North from these sites. For tall buildings, the amplification levels are in range of 6-8 at Mathura, Agra and Firozabad. This implies that significant damage to the infrastructure is expected due to the occurrence of a moderate earthquake within NCR.

(iv) The predominant frequencies are found to be in the range 2.0-5.0 Hz for the regions having older alluvium sediments while in the range 5.5-7.0 Hz for the region with the younger alluvium deposits.

(v) The accelerograms have been synthesized at bedrock level as well as at surface level for 144 sites of NCR using a simple and computationally efficient semi-empirical envelope technique. The simulated accelerograms are due to five scenario earthquakes at identified source zones namely Mathura Fault, Sohna
Fault, Delhi Haridwar Ridge, Great Boundary Fault and the Moradabad Fault. The semi-empirical technique adopted for the simulation has been found to be suitable for the NCR. The simulated time history of strong ground motion is important for designing of critical structure in the region. The higher pga values estimated for the sites near the source zones are found to be in agreement with those of obtained using different techniques.

(vi) An attenuation relation of pga with distance has been identified for NCR.

(vii) The scenario hazard maps have been prepared by showing the spatial distribution of pga and spectral acceleration values for different periods corresponding to the periods of different storey buildings. The spatial distribution of pga values show that the cities like Sonepat, Faridabad, Delhi, Gurgaon, Moradabad in NCR show high to severe seismic hazard.

(viii) The decay rate curves of pga with distance show, in general, that the pga values drop faster in the near distance range (up to 20-25 km) as compared to larger distance range (> 25 km). The decay rate of pga value is found to be faster in case of Moradabad fault as compare to other faults.

(ix) The seismic exposure of the population of NCR has been estimated using the decay of pga values with distance. This shows that the population of 4.78 millions is exposed to moderate seismic risk and 8.28 millions to high risk in case an earthquake of magnitude 6 occurs at Sohna fault. The seismic exposure of the population due to scenario earthquakes is important to utilize the resources properly if an earthquake occurs.

(x) It has been found in the present analysis that the maximum contribution towards the seismic hazard is from the Sohna Fault, Mathura Fault and Delhi Haridwar Ridge.

(xi) The scenario hazard maps based on spectral acceleration values corresponding to the natural periods of different storey buildings show that the different types of buildings except high rise buildings are at higher risk level in cities like Sonepat, Bahadurgarh and adjoining regions if an earthquake of magnitude 6 occur at Sohna fault. For the same earthquake the high rise buildings at Faridabad, Gurgaon and Noida are exposed to comparatively low level of hazard level.
The single and double storey buildings in Delhi and surroundings cities like Gurgaon, Noida, Faridabad are more vulnerable to seismic hazard if Mathura fault generates an earthquake of magnitude 6.5 and the hazard level due to same earthquake is low for high rise buildings in Sonepat region.

It has been found that the buildings of Delhi region are relatively less vulnerable if an earthquake of magnitude 6 happens to occur either at Moradabad fault or at Great Boundary fault.

The decay of spectral acceleration values with distance for the earthquake at Sohna fault is found to be fast up to 40 km as compare to the case with the Matura fault and the Delhi Haridwar ridge.

The scenario hazard maps of NCR presented in this thesis provide a suitable basis to strengthen the built environment in the region to resist the effects of a future earthquake and therefore to reduce the expected losses considerably. Also, the new constructions should take this information into account for incorporating appropriate safety measures against destruction from such earthquakes. These maps are useful for the administrators and planners to mitigate the seismic hazard in the region.

6.3 **Scope for Future work:**

The information presented in the scenario hazard maps presented here can be superimposed by the maps showing the locations of different types of the buildings and large structures and also population estimates on GIS platform. This will provide ready to use maps to the administrators and NGOs involved in the mitigation of seismic hazard. The information provided in the present thesis may be used for the microzonation studies of the region.