CHAPTER VI

CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

This study represents a method of the combined remote sensing, GIS and field investigation approach to landslide hazard mapping. The basis of this method is the assumption that the distribution of past landslides, interpreted from remote sensing, can indicate the probability of future landslide event. The rationale involves establishing relationships with several independent variables, such as are lithology, lineament, land use / land cover, elevation, slope angle, slope aspect, flow direction, and NDVI, which are then used to model combined probability and weighting. The GIS has been demonstrated to be a convenient tool for (1) storing and displaying data, (2) analyzing relationships between landslides and variables, and (3) generating landslide hazard maps. The techniques are directed toward and operational methodology for producing provisional regional landslide hazard maps effectively.

Based on the results of bivariate probability and weighting model and remote-sensing interpretation (Landsat 7 ETM and IKONOS) integrated with ground-truth from preliminary field investigation in the Nan study area, northern Thailand, the conclusions can be drawn as the following;

1) Very High landslide hazard occur in mountainous area in the northern and northeastern part of Nan province; Chalerm Phrakiat, Song Khwae, Thung Chang, Chiang Klang, Pua, Bo Klua District.
2) In the Nan study area, lithology, lineaments and land use / land cover types are effective factor for landslide occurrences.
3) The bivariate probability and weighting model can modify to use with the regional-scale landslide hazard zonation analysis.

6.2 Recommendations

1) Given the requirement for landslide hazard maps at the regional to national scale, interpretations of enhanced Landsat 7 ETM imagery provide a practical means of mapping major landslide-landscape terrain features, past and recent landslide events and lineaments. The use of the reflected infrared bands TM 4, 5, and 7, combined as RGB false-colored composite, provide a relatively image with good discrimination of ground materials. Once geometrically registered to the national map projection, relevant geological, infrastructural and cultural, information can be readily extracted from the imagery and entered into the GIS.
2) The use IKONOS imagery provides the reliable means of obtaining high resolution information on the extent of landslide scar-scouring interpretation and it costless.
3) Before any analytical work can be done on the GIS, it is necessary to build a database of spatially co-registered information. The extent of this database, and thus the reliability of the final hazard map, will depend on the availability and quality of existing data and on what new information can be obtained. The work of capturing existing data involves digitizing analogue data, as well as converting existing digital data to an appropriate format. This is a time-consuming involving a large amount of effort. The size of the task should not be under estimated. Databasing should be regarded as an ongoing activity.
4) Once a database is established, the GIS can be used to produce customized map outputs quickly and at minimal cost. As further data become available, more reliable thematic interpretations can be produced.
5) The ideal GIS for landslide hazard map production, suitable for all situations, probably does not yet exist. Vector-based GIS is efficient for storing data and providing high quality map output, but raster-based GIS systems are needed

for analyzing spatial relationships variables. Developments are slowly moving towards combining both functionalities. The choice of GIS should be taken for landslide hazard assessment.

6) The analytical capabilities of the raster-based GIS provide a means of "modeling" the distribution of landslides in terms of independent variables (e.g. lithology, slope, etc.). An important result of the present study was the development of a systematic statistical approach to archive this. It begins by calculating the proportion of landslide to non-landslide pixels falling within each class of each variable (e.g. open forest on the land use map), and comparing these values with the regional average. This indicates weather the landslide frequency in a class is higher or lower than might be expected over the area as a whole. "Weights" are calculated for each class of each variable according to the strengths of the correlations established. For this study, landsliding was separately compared against rock type, slope steepness, slope aspect, elevation, and proximity to lineaments. Once the relative weights are established, combination of variables can produced by summing the weight class by class over the area. The effect of combining factors which individually influence or relate to landsliding to different degrees is to improve progressively the reliability of the model. The statistics allow the combined variable map to be quantified in terms of relative hazard probability.
7) The value and reliability of the model developed depend on the input data. Relatively few data layers were used in the pilot study and some of these were much generalized. An improved result might be expected if a new update data or maps were available.
8) Finally, although the approach is less than rigorous, it would appear to provide the basis for a workable solution capable of providing provisional regional hazard maps in Nan study area in a realistic condition. The remote

sensing and GIS approach can provide the landslide hazard zonation map but many factors combine to cause a landslide and the map produce by such methods have their limitations. However, used properly, they can provide valuable information for planning and disaster preparedness.

A review is needed to define priorities for landslide hazard mapping in Nan Province area and to devise a long term strategy for landslide hazard mitigation. Consideration should be given to identifying those areas potentially most at risk in terms of infrastructure, new developments and population. Flexibility should be included to allow responses to new requirements and events.