CHAPTER 1

INTRODUCTION

Every year, natural disasters have claimed several thousand lives all over the world. This is quite costly to the world economy both in human affairs and in economical aspects as natural disasters have major direct and indirect economic and socio-economic effects as well as physical destruction. Unfortunately, the impact of these disasters is more severe in many developing countries as the developed countries have already created disaster mitigation and disaster preparedness programs while the developing countries normally only give in to such vulnerability.

The natural hazard events are the disasters of a natural phenomenon or combination of phenomena, such as landslides, floods, earthquakes, volcanic eruptions, tsunamis, etc., which can cause some loss of lives and property damage. Literally, no where on earth is safe from the impact of the natural hazards. Due to an increasing population density and non-existing or inadequate development plan, especially in Thailand, more and more people are prone to such disasters.

1.1 Rationale

On 11th August 2001 (here after referred to as 8/11) at 3:30 a.m., a disastrous debris flow and associated debris flood had severely damaged Ban Nam Ko Yai situated on the alluvial fan just below the canyon mouth of the same-named Nam Ko Yai stream, a tributary of Pa Sak river in Amphoe Lom Sak, Changwat Phetchabun, central Thailand. The muddy flood water, full of debris of fallen trees, had destroyed several houses along the stream banks and claimed 136 lives with an estimation of over 200 million Bath of the property damage (Secretariat Office of Government, 2002). This is one of the so many severe tragedies caused by the debris flows and debris floods in Thailand in the past few decades.

A complete understanding of the processes and relevant parameters that influence this 8/11 incident in Nam Ko Yai sub-catchment and the alluvial fan below in terms of action, source areas and run-out zones, as well as the evaluation of the potential for debris-flow and debris-flood hazards in this event has never been accomplished. Besides, the repetition of such debris flow and debris flood in this area is yet to be evaluated. A case study analysis of this event should also provide essential basic information to mitigate any future debris flows and debris floods in this area and the areas of similar geographical conditions.

In general, debris flows and related sediment flows are fast-moving flow-type landslides composed of slurry of rock, mud, organic matter, and water that move down drainage-basin channels to the alluvial fan. Debris flows and related sediment flows may be initiated on the adjacent steep slopes or within channels by one of the two processes, by landsliding or by sediment bulking of surface water flows during periods of rapid addition of water to the terrain, either by intense rainfall or rapid snowmelt. Flows typically incorporate additional sediment and vegetation as they travel down channel (Cannon, 1997). When flows reach an alluvial fan formed by such previous flows, they lose channel confinement. Then the flows spread laterally and deposit more entrained sediment overbanks. These alluvial fans are normally the favorable living sites so the settlements are merely vulnerable to such flows and floods. Thus a debris-flow-hazard evaluation is essential when development is planned on alluvial fans (U.S. National Research Council, 1996).

Variations in sediment-water concentrations produce a continuum of sediment-water flow types that build alluvial fans. Beverage and Culbertson (1964), Pierson and Costa (1984), and Costa (1988) describe the following flow types based on generalized sediment-water concentrations and resulting flow behavior: stream flow (less than 20% sediment by volume), hyperconcentrated flow (20 to 60% sediment by volume), and debris flow (greater than 60% sediment by volume). These categories are only approximations because the exact sediment-water concentration and flow type depend on the grain-size distribution and physical-chemical composition of the flows. Also, field observations and video recordings of poorly sorted, water-saturated sediment provide evidence that no unique flow type adequately describes the range of mechanical behaviors exhibited by these sediment flows (Iverson, 2003). Also, all three flow types can occur together during a single event. The U.S. National Research Council (1996) considers stream, hyperconcentrated, and debris-flow types of alluvial-fan flooding in the report on Alluvial-Fan Flooding. The term debris flood had been used in Utah to describe hyperconcentrated flows (Wieczorek and others, 1983). Debris floods were also referred to in many other terms in the technical literatures, including waterflood with large sediment load (Costa and Jarrett, 1981), sediment flow (Ikeya, 1981) and mud flood (U.S. National Research Council, 1982).

In the last two decades the "state-of-the-art" of evaluation of debris-flow hazard continues to evolve as our knowledge of sediment-flow processes advances. As new techniques become available and are generally accepted, they should be used in future hazard evaluations. Wieczorek and others (1983) proposed the techniques to evaluate potentials for a debris flow-flood that should answer the following questions; relationship between rainfall (or snowmelt) and landslide movement, stability of the partly-detached landslides, process of transformation from landslide to debris flow, incorporation of channel materials by debris flow, transition from debris flow to debris flood, factors that control debris flow run-out, and recurrence of debris floods-flows at canyon mouths.

According to U.S. National Research Council (1996), an alluvial fan flooding hazard is indicated by three related criteria, namely, flow path uncertainty below the hydrographic apex, abrupt deposition and ensuing erosion of sediment when a stream or debris flow loses its competence to carry eroded material from a steeper upstream source area, and an environment where the combination of sediment availability, slope, and topography creates an ultrahazardous condition for which elevation on fill will not reliably mitigate the risk.

The guidelines for the geologic evaluation of debris-flow hazard on alluvial fans were also proposed by Giraud (2005) to be necessarily for safe and appropriate land use that could prevent loss of life and property damage. In general, the purpose of a geologic evaluation is to determine whether or not a debris-flow hazard exists in the area of interests, to describe the hazard if exist, and if needed, to provide geologic parameters necessarily for hydrologists and engineers to design risk-reduction measures. Determination of active depositional areas, frequency, and magnitude (volume) of previous flows, and likely impacts of future sedimentation events are the expected outputs from such geological evaluation. Dynamic analysis of debris flows-floods using hydrologic, hydraulic, and other engineering methods to design site-specific risk-reduction measures should also be addressed by these guidelines.

However, a geologic evaluation of potential for debris-flow- and related-sediment-flow hazard requires a large spatial variability of the required input data, while the techniques of analysis may be very costly and time-consuming. Over the past three decades, the increasing availability of remote sensing technology and geographic information systems (GIS) has created opportunities for a more detailed and rapid analysis of landslide hazard in large areas (Van Westen, 1994). Because landslides directly affect the ground surface to give scar records, remote sensing techniques are hence suitable to slope instability studies. The term remote sensing being used here is in the widest sense, including aerial photography and imagery obtained by satellites and any other remote-sensing techniques. Remote sensing is particular useful when stereo images are used because they depict in the stereo model the typical morphologic features of landslides, which often provide diagnostic information concerning the type of movement. Also, the overall terrain conditions, which are critical in determining the susceptibility of a site to slope instability, can profitably be interpreted from remote sensing data. GIS can be used to update, manipulate, integrate and analyze the spatially distributed data, and to prepare the final maps related to the purpose of a geologic evaluation of debris-flow- and related-sediment-flow-hazard. It is essential that the potential source areas and run-out zones of debris flows are correctly assessed and mitigation measures adopted using modern mapping and monitoring techniques (Corominas and others, 1996). Detailed specification of the above mentioned literatures will be explained in the following chapter.

Therefore, a debris flow-hazard evaluation is necessarily for safe and appropriate land use determination to prevent loss of life and property damage. Understanding the processes that govern a debris-flow initiation, debris-transport and water-transport action in the drainage basin, sediment bulking, and deposition on the alluvial fan is vital to a hazard evaluation. Debris-flow hazards may be managed differently in terms of land-use planning and protective measures, but because debris-flow and stream-flow hazards are closely associated, concurrent evaluation of both debris-flow and stream-flow components of alluvial-fan flooding is often beneficial.

This thesis addresses only a hazard evaluation associated with debris-flow and debris flood (or hyperconcentrated-flow), sediment-water concentrations, and not stream-flow flooding on alluvial fans. The term *flow-flood* will be conveniently used here in a general way to include all flows within the debris-flow and debris flood (or hyperconcentrated-flow) sediment-water concentration range that are difficult to distinguish from each other based on their deposits.

1.2 Objectives

The purposes of this present study are

- To investigate the parameters influencing the case-study 8/11 flow-flood occurrence in Nam Ko Yai sub-catchment,
- To identify the potential source area, run-out zone, and depositional area of the 8/11 flow-flood occurrence in Nam Ko Yai sub-catchment and the alluvial fan,
- To determine the evidences of the potential for hazards from the flow-flood occurrence in Nam Ko Yai sub-catchment and the alluvial fan, and
- To define the relationship between the sedimentary sequences and the flow-flood occurrence in the alluvial fan.

1.3 Hypothesis

As the "state-of-the-art" of debris-flow- hazard evaluation continues to evolve as our knowledge of sediment-flow processes advances in the last two decades. The techniques of landslide hazard assessment especially for debris flow-hazard evaluation proposed by Wieczorek and others (1983), Van Westen (1994), Corominas and others (1996), U.S. National Research Council (1996), Giraud (2005) become available and are generally referred to. Besides, flow-flood susceptibility analysis by using univariant probability analysis (Lee and Min, 2001) is a simplest technique which can attempt to assess the probabilistic relationship between relevant environmental parameters and the occurrence of landslides in a given region. Those techniques should possibly be applicable for evaluating the potential of flow-flood in the Nam Ko area as the first case study in Thailand.

Theoretically, the major parameters being suspected to affect this 8/11 event should be the landforms, slope gradient, underlying materials, land cover and land use, and heavy rainfalls. Whereas the tropical storm “Usa-ngi” that passed through here with the unusual high amount of rainfalls during the first two weeks of August 2001, the impropriate land use in the strongly deforested of Nam Ko Yai sub-catchment are primarily blamed to be the major causes of this tragedy by the publics and academics. Thus this research attempts to apply those "state-of-the-art" techniques of evaluation for flow-flood hazard to identify the flow-flood hazard, to determine parameters necessary for the initiation of the flow-flood process, and to determine whether or not a flow-flood hazard can occur again.

1.4 Scope and limitation

This thesis is limited to identify the parameters influencing the 8/11 flow-flood occurrence by the field-knowledge base integrated with the application of the remote sensing and geographic information system (GIS) techniques. Detailed field investigation was conducted only in the main target areas that were analyzed as the potential source areas, run-out zones, and depositional areas of the flow/flood in Nam Ko Yai sub-catchment. In addition, detailed investigating of sedimentary sequences to define the relationship between the sedimentary sequences and the flow-flood occurrence were done only in the active alluvial fan.

Dynamic analysis of flow-flood using hydrologic, hydraulic, and other engineering methods to design site-specific risk-reduction measures was not addressed in detail in this research. Ranges for debris-flow bulking rates, flow volumes, runout distances, deposit areas, and deposit thicknesses were neither studied, thus further research is necessary to quantify the physical characteristics of debris flows all over the sub-catchment. The methods outlined in this thesis are considered to be practical and reasonable for obtaining planning, design, and risk-reduction information, but these methods may not be applicable in all cases.

1.5 Location of the study area

The study area (Figure 1-1) is located in the northwestern corner of the main upper Pa Sak catchment at the foot of Khao Ko and Phu Hin Rong Kla mountains of Phitsanulok-Phetchabun range, central Thailand. The area comprising approximately 75 square kilometers, geographically defined as Nam Ko Yai sub-catchment and its alluvial fan, is in Amphoe Lom Sak, Changwat Phetchabun (Figure 1-2). Ban Nam Ko Yai is situated on the alluvial fan. The extents of the coordinates of the study area are approximately defined as 1868500 N, 719600 E in the northwestern edge and 1856000 N, 735500 E in the southeastern edge in Universal Transverse Mercator projection with 47 North zone in Indian 1975 ellipsoid. The sub-catchment configuration is north-southerly trending upstream, then southeasterly. The sub-catchment area is 14 km long and 5 km wide. The upstream rims are bounded by the steep slopes to a maximum altitude of 1,746 m in the northwestern part, down to the gentler slopes then flat rolling sub-catchment terrain and the alluvial fan at an altitude of 160 m.

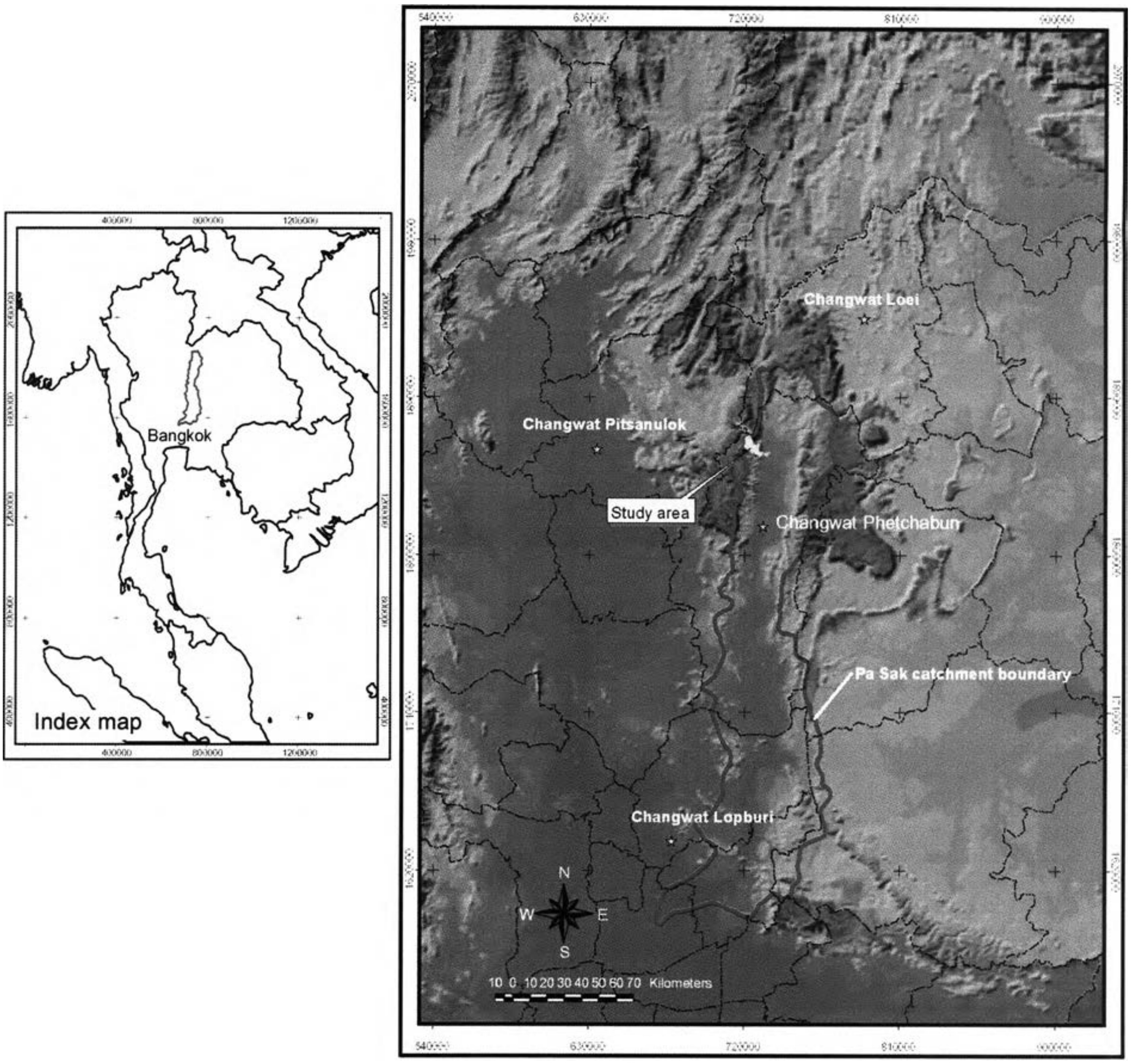
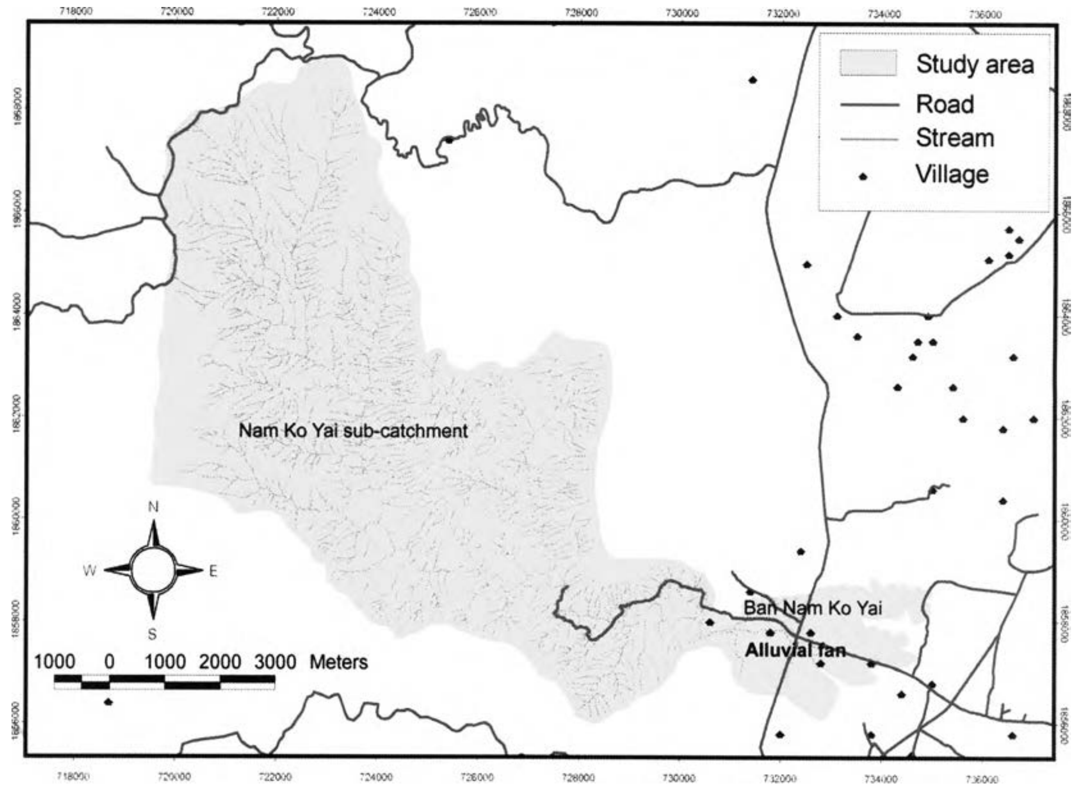
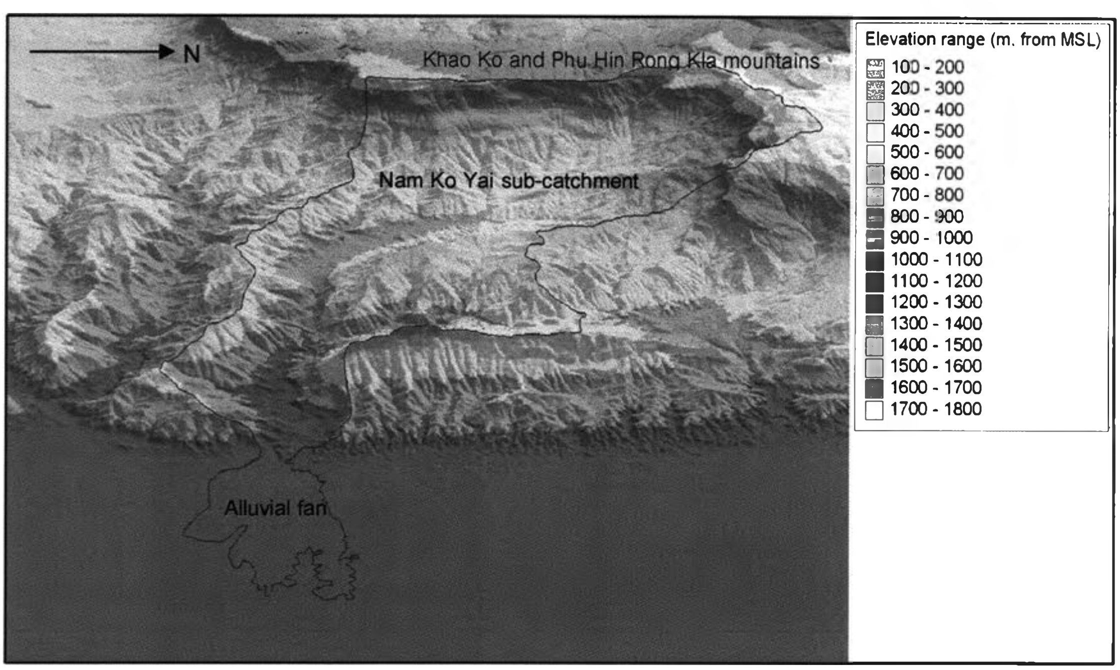


Figure 1-1 Geographic setting of the study area.



a)



b)

Figure 1-2 a) Location of the study area with important reference locations, and

b) Three-dimensional drape of Nam Ko Yai sub-catchment and its alluvial fan boundary (black color line) of the study area and surrounding terrains.

1.6 Expected outputs

The expected outputs of this thesis consist of:

- Debris flow-flood susceptibility in Nam Ko Yai sub-catchment.
- Three dimension models and maps representing the potential source areas, run-out zones, and depositional areas of the 8/11 flow-flood in the study area.
- Evidence and relationship between the sedimentary sequences and the flow-flood occurrence in the alluvial fan.
- Criteria to determine the potential for the future disastrous events in the study area.

These results should supply planners and decision-makers with adequate and understandable information for a more effective planning with appropriate strategies for reducing and mitigating the debris-flow hazards and related phenomena in a long term risk that may be repeatedly occurred in the study area as well as in other areas of similar geographical conditions, especially, along the western flank of Phitsanulok-Phetchabun mountain range.

1.7 Research methodology

To accomplish the aims of this thesis, the research involves four sequential steps are designed. Each of which is described as follows:

1.7.1 Preparation

This step includes:

- Literature review of the related researches in the study area, southern Thailand, and other countries.
- Acquisition and study of the previous basic data acquisition, i.e. aerial photographs (1:25,000 and 1:50,000 scale), satellite images of medium resolution (Landsat), topographic map, geologic map, and land use map

to understand the topography, geology, and land use pattern of the study area as general background information.

- Intensive comprehension on the conceptual framework of landslide and especially the criteria to evaluate potential of flow-flood occurrence.

1.7.2 Field investigation

The field investigation and direct observation were carried out as follows:

- Reconnaissance to understand and recognize the limitation in the study area for preparing the data and related plan that would be used in further steps of the field investigation
- Intermediate field investigation to investigate and define the physical conditions, geologic characteristics and soil characteristics that may affect the occurrence of flow-flood, and to conduct ground-truth to inspect the correctness of the analyzed results from the remote sensing image analysis and interpretation
- Detailed survey to collect the elevation data of the scar-scouring from 8/11 flow-flood along the both sides of Nam Ko Yai stream, to interview local people who witnessed in the 8/11 event, and to collect samples of weathered products of the rock formations that were sensitive to the flow-flood occurrence especially in the major potential source areas and run-out zones of Nam Ko Yai sub-catchment. The results from the detailed survey are used as evidences of the potential source areas, run-out zones, and depositional areas of the 8/11 flow-flood.
- Investigation the sedimentary sequences to define the relationship between the sedimentary sequences and the flow-flood occurrence in the alluvial fan.
- Performing a resistivity survey in the alluvial fan area to estimate the subsurface characteristics of the sedimentary sequences

1.7.3 Laboratorial studies

The laboratorial analysis is conducted as follows:

- Thematic (GIS and remote sensing) data preparation. These inventory data consist of topography, geology, geomorphology, terrain unit, morphometry (digital elevation model (DEM), slope, aspect), land use and land cover, hydrology (drainage network, river and basin configurations), meteorology of rainfall intensity. Softwares of geographic information system (GIS) and remote sensing (ArcInfo, ArcView 3.3, ArcView 3D Analysis, ArcView Image Analysis, and ERDAS IMAGINE 8.5) are applied in developing, manipulating, and analyzing the digital data. The digital elevation data is converted from a 1:20,000 scale digital topographic map (10 m contour interval) derived from Land Development Department (LDD).
- Interpretation of aerial photographs (1:25,000 and 1:50,000 scale), orthophotograph rectified images (1:25,000 scale), and satellite images of medium and high resolution (Landsat TM and IKONOS) that were acquired before and after the 8/11 flow- flood event. This sub-step was conducted to develop the new data (e.g. scars-scourings from the 8/11 flow-flood event), and update or improve the secondary data from the above data pre-processing sub-step. These inventory data were also checked from ground-truth information from brief field traverses to inspect the accuracy in the intermediate field investigation.
- Debris flow-flood hazard analysis in Nam Ko Yai sub-catchment in terms of debris flow-flood susceptibility analysis and calculation of debris flow-flood susceptibility is conducted. This is preliminary debris flow-flood hazard analysis by univariant probability method to present the spatial relationship between the scar-scouring locations and each of available flow-flood influencing parameters (as theoretically mentioned) in Nam Ko Yai sub-catchment, namely, slope, landform topography, geology, soil group unit, soil thickness, land cover, and stream proximity, respectively.

The GIS was used to compile a vast amount of data efficiently, and a statistical program was used to maintain specificity and accuracy.

- Laboratory geotechnical testing of the weathered products of the rock formation collected from the detailed survey of field investigation step. This defines some engineering properties of sedimentary properties and basic geotechnical properties (e.g. the grain size analysis, determination of Atterberg limits and indices, natural moisture content, and shear strength) that were used to identify the sensitivity from the 8/11 flow-flood occurrence.

1.7.4 Synthesis, discussion and conclusions

This step includes:

- Synthesizing, discussing and concluding debris flow-flood susceptibility in Nam Ko Yai sub-catchment.
- Synthesizing, discussing and concluding the potential source areas, run-out zones, and depositional areas of the 8/11 flow- flood occurrence in Nam Ko Yai sub-catchment and the alluvial fan.
- Synthesizing, discussing and concluding the criteria of the potential for hazards from the flow-flood occurrence in the study area.
- Synthesizing, discussing and concluding the relationship between the sedimentary sequences and the flow-flood occurrence in the alluvial fan.

In order to accomplish the objectives of this research, the schematic diagram illustrating the present methodology system was designed as shown in Figure 1-3.

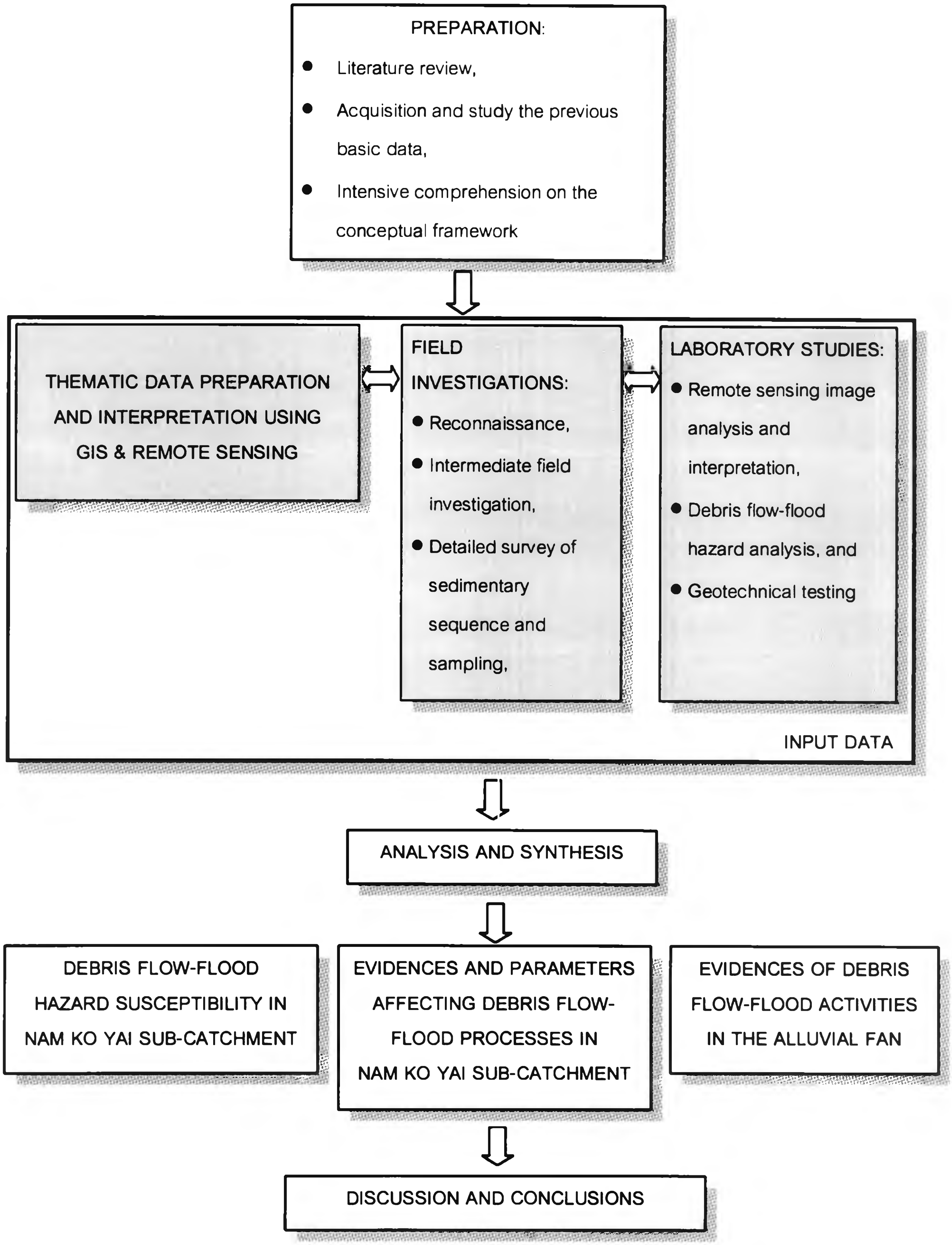


Figure 1-3 Schematic diagrams illustrating the research methodology system.

1.8 Components of the thesis

This thesis comprises eight chapters including this introductory Chapter 1. Chapter 2 is initiated with an intensive comprehension on basic concepts on evaluation of the potential for debris-flows and related sediment-flows as well as the previous investigations from the related technical literatures are presented. The applications of the remote sensing and geographic information system (GIS) in landslide hazard assessment are briefly reviewed.

Since the possibilities and limitations of the proposed methodology can only be evaluated critically when field data are available. Data preparation and interpretation in terms of types of input data and data production stage is given in Chapter 3. In this chapter, data input from thematic data pre-processed with the application of geographic information system (GIS) and remote sensing techniques are produced and interpreted. Following the data preparation and interpretation stages, debris flow-flood hazard analysis of Nam Ko Yai sub-catchment by the statistic approach is proposed in Chapter 4. Debris flow-flood susceptibility is preliminary analyzed using the influencing parameters by univariant probability method to present the spatial relationship between the detected scar-scouring locations and each of the influencing parameters in the sub-catchment. Besides, calculation of debris flow-flood susceptibility in the sub-catchment is also proposed in this chapter.

The core of this thesis is presented in the Chapters 5 and 6. The investigation of the available and new evidences and parameters affecting debris flow-flood processes, namely, evidences of geotechnical properties of soil and rock samplings, as well as evidences of suspected temporary landslide dam location and the channel configuration in Nam Ko Yai sub-catchment are presented in Chapter 5. Recognition and characterization of the alluvial fan, by defining its activeness as well as the geomorphology and the stratigraphic recognition of the previous alluvial fan deposits are the subjects in Chapter 6.

In Chapter 7 the attention is focused on discussion of the debris flow-flood susceptibility results, the flow-flood event reconstruction and its potential, and FLO-2D simulation results for validation of the suspected temporary landslide dam occurrence in the central part of Nam Ko Yai sub-catchment, respectively. Finally, the evaluation of potential for the 2001 flow-flood in Nam Ko Yai sub-catchment and its alluvial fan are summarized and concluded with further recommendation in Chapter 8.