Landslide : occurrence, risk and management

Worawoot TANTIWANIT

What is Landslide ?

Landslide is the downslope movement of soil or rock material under the influence of gravity.

They usually are destructive phenomena and can cause the loss of life and economic.

Top 10 most important Mass movement wet disasters for the period 1900 to 2012 sorted by economic damage

Country	Date	Damage (000 US$)
Peru, Landslide	Jan. 1983	988,800
China P Rep, Landslide	1/5/1998	890,000
China P Rep, Landslide	7/8/2010	759,000
Italy, Landslide	14/12/1982	700,000
Switzerland, Avalanche	21/2/1999	685,000
Italy, Landslide	28/7/1987	625,000
Ecuador, Landslide	28/3/1993	500,000
Guatemala, Landslide	4/9/2010	500,000
Soviet Union, Landslide	10/3/1989	423,000
Bolivia, Landslide	8/12/1992	400,000

Created on: May-22-2012. - Data version: v12.07 Source: "EM-DAT: The OFDA/CRED International Disaster Database www.em-dat.net - Université Catholique de Louvain - Brussels - Belgium"

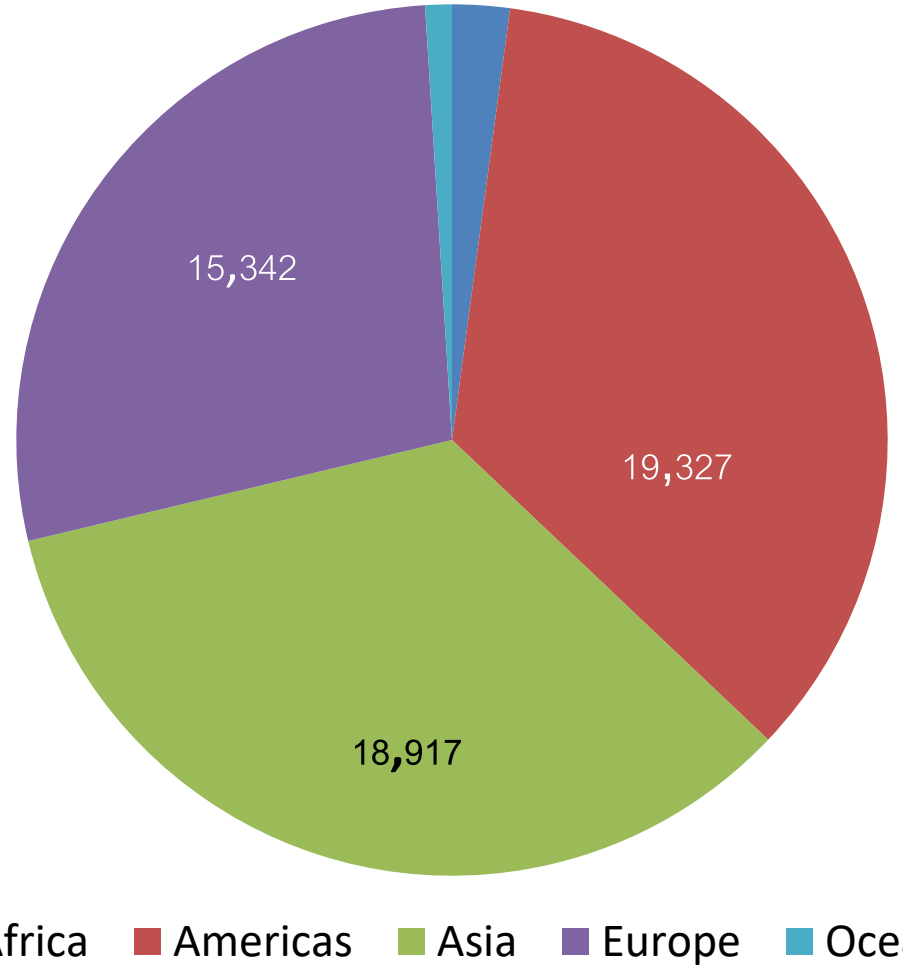
Top 10 most important Mass movement wet disasters for the period 1900 to 2012 sorted by numbers of killed

Country	Date	No Killed
Soviet Union, Landslide	1949	12000
Peru, Landslide	Dec.1941	5000
Honduras, Landslide	20/9/1973	2800
Italy, Landslide	9/10/1963	1917
China P Rep, Landslide	7/8/2010	1765
Philippines, Landslide	17/2/2006	1126
India, Landslide	1/10/1968	1000
Colombia, Landslide	27/9/1987	640
Peru, Landslide	18/3/1971	600
China P Rep, Landslide	23/3/1934	500

Created on: May-22-2012. - Data version: v12.07 Source: "EM-DAT: The OFDA/CRED International Disaster Database www.em-dat.net - Université Catholique de Louvain - Brussels - Belgium"

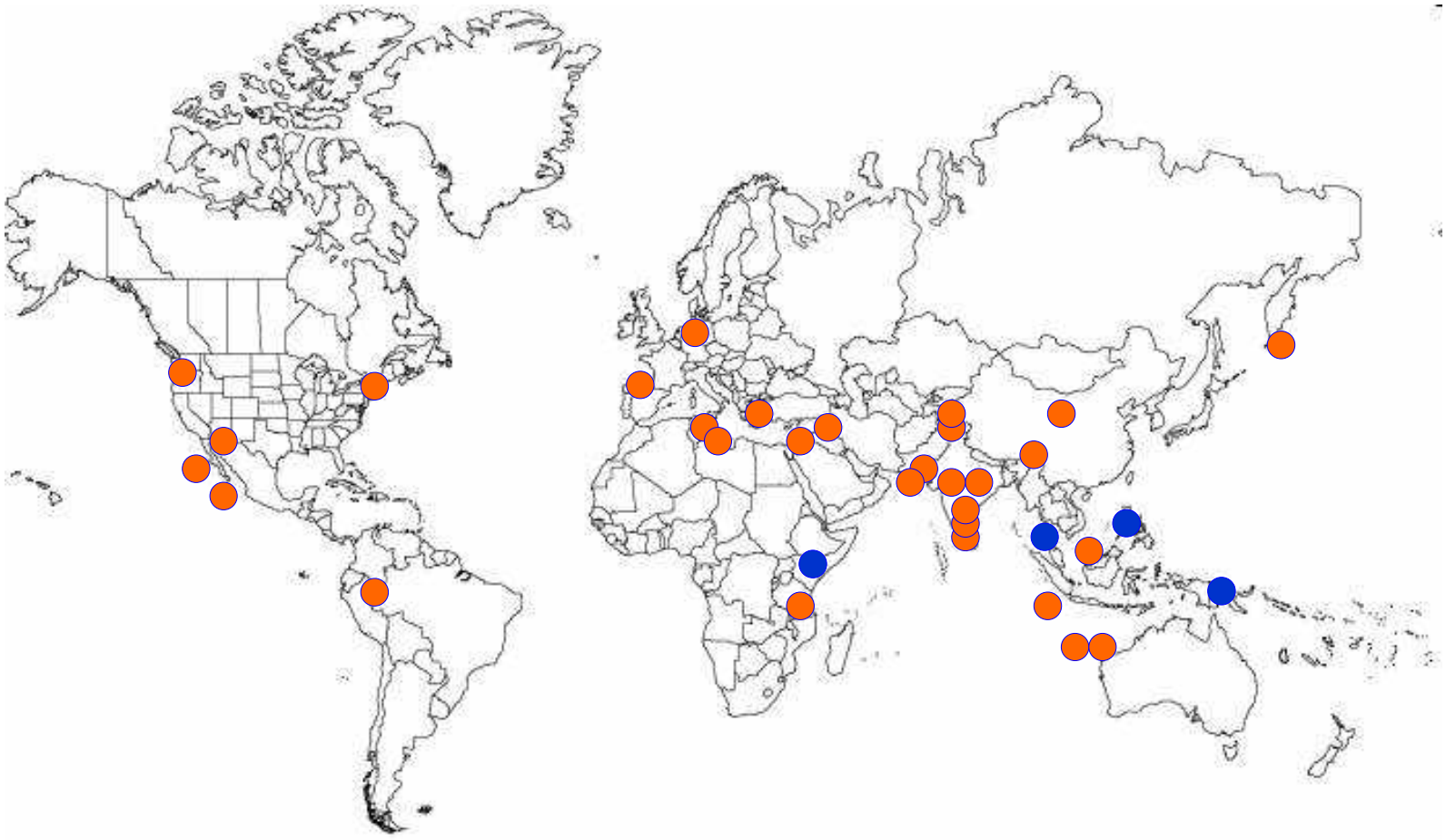
Summarized Table of Mass movement wets sorted by Continent from 1900 to 2012

	Killed
Africa	1179
Americas	19327
Asia	18917
Europe	15342
Oceania	546



Source: "EM-DAT: The OFDA/CRED International Disaster Database

Landslides are Widespread!



- January-May 2005 events
- January-May 2012 events

Modify after: Oddavar NGI,June 2005

Landslide: January-May 2012 events

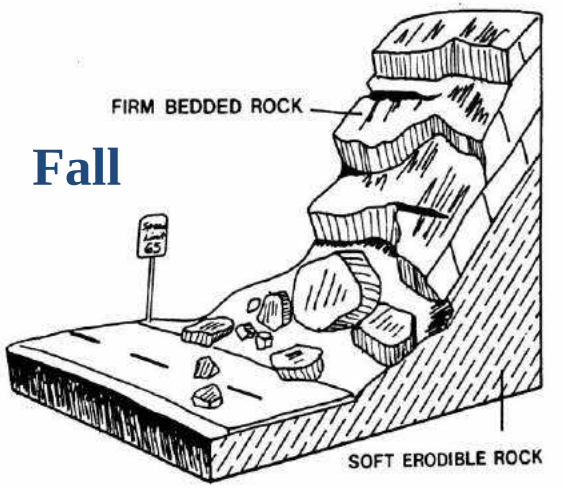
- **Jan 2, 12 - Jan 8, 12**
- 0002-2012 - Landslide | Pantukan, Compostela Valley, Philippines, AS
- **Jan 9, 12 - Jan 15, 12**
- 0011-2012 - Flash Flood | Thailand, South
- **Jan 30, 12 - Feb 5, 12**
- 0052-2012 - Landslide | Papua New Guinea
- **Apr 2, 12 - Apr 8, 12**
- 0088-2012 - Landslide | Nairobi, Nairobi Area, Kenya, AF

Source: "EM-DAT: The OFDA/CRED International Disaster Database

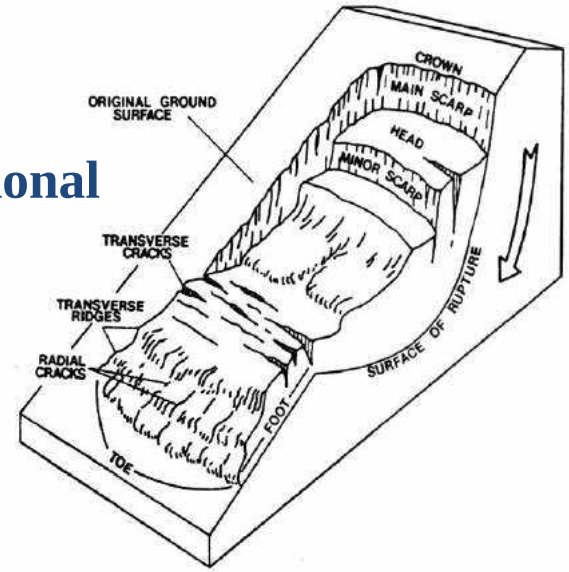
Classification of Landslide

Type of Movement	Type of Material		
	Bedrock	Engineering Soils	
		Predominantly Coarse	Predominantly Fine
Fails	Rock fall	Debris fall	Earth fall
Topples	Rock topple	Debris topple	Earth topple
Slides	Rock slump	Debris slump	Earth slump
Rotational	Rock block slide	Debris block slide	Earth block slide
Translational	Rock slide	Debris slide	Earth slide
Lateral spreads	Rock spread	Debris spread	Earth spread
Flow	Rock flow	Debris flow	Earth flow
	(deep crack)	(soil creep)	(soil creep)
Complex	Combination of two or more principal types of movement		

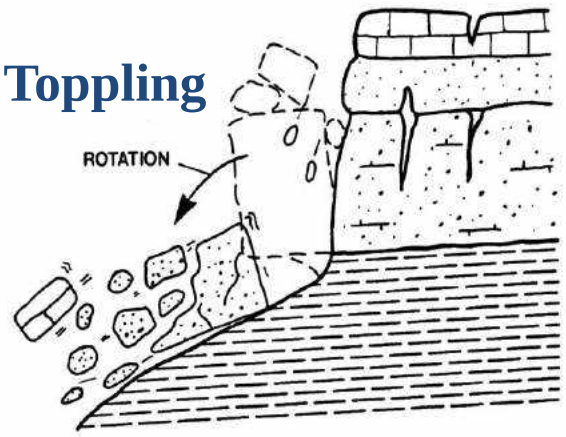
Fall



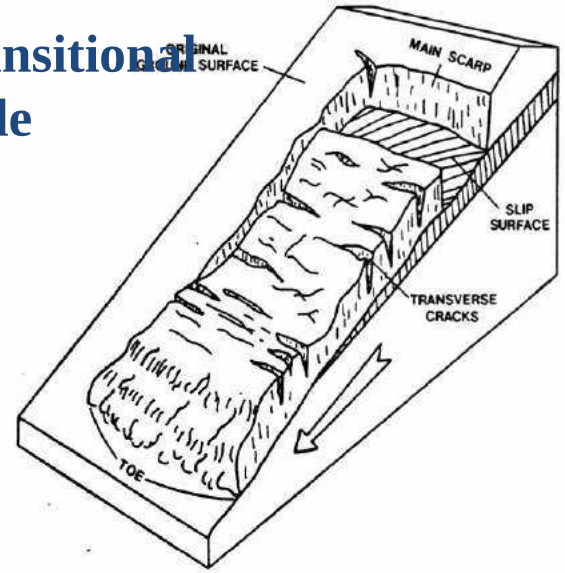
Rotational Slide



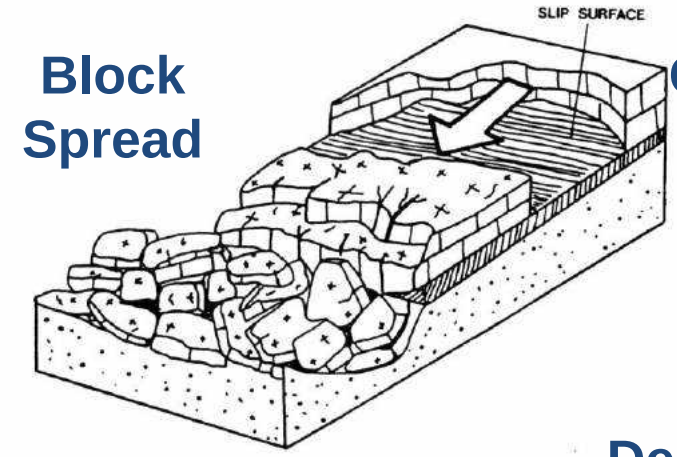
Toppling



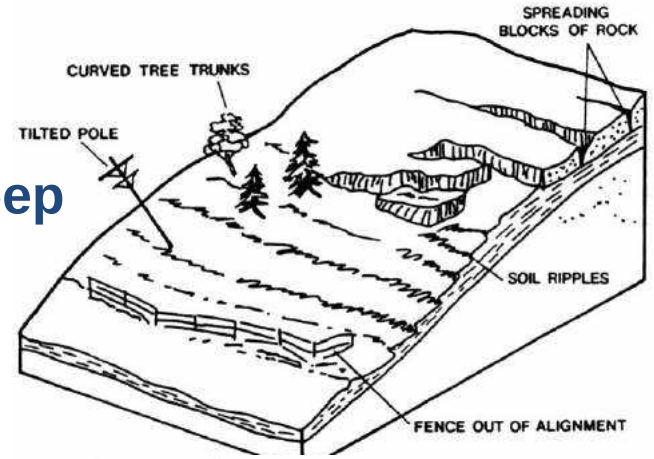
Transitional Slide



Block Spread

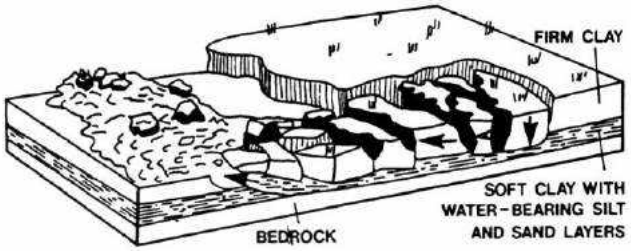


Creep



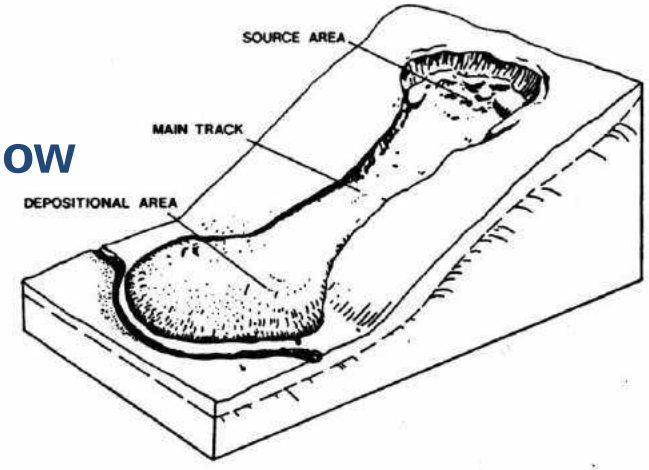
Debris Fan

Lateral



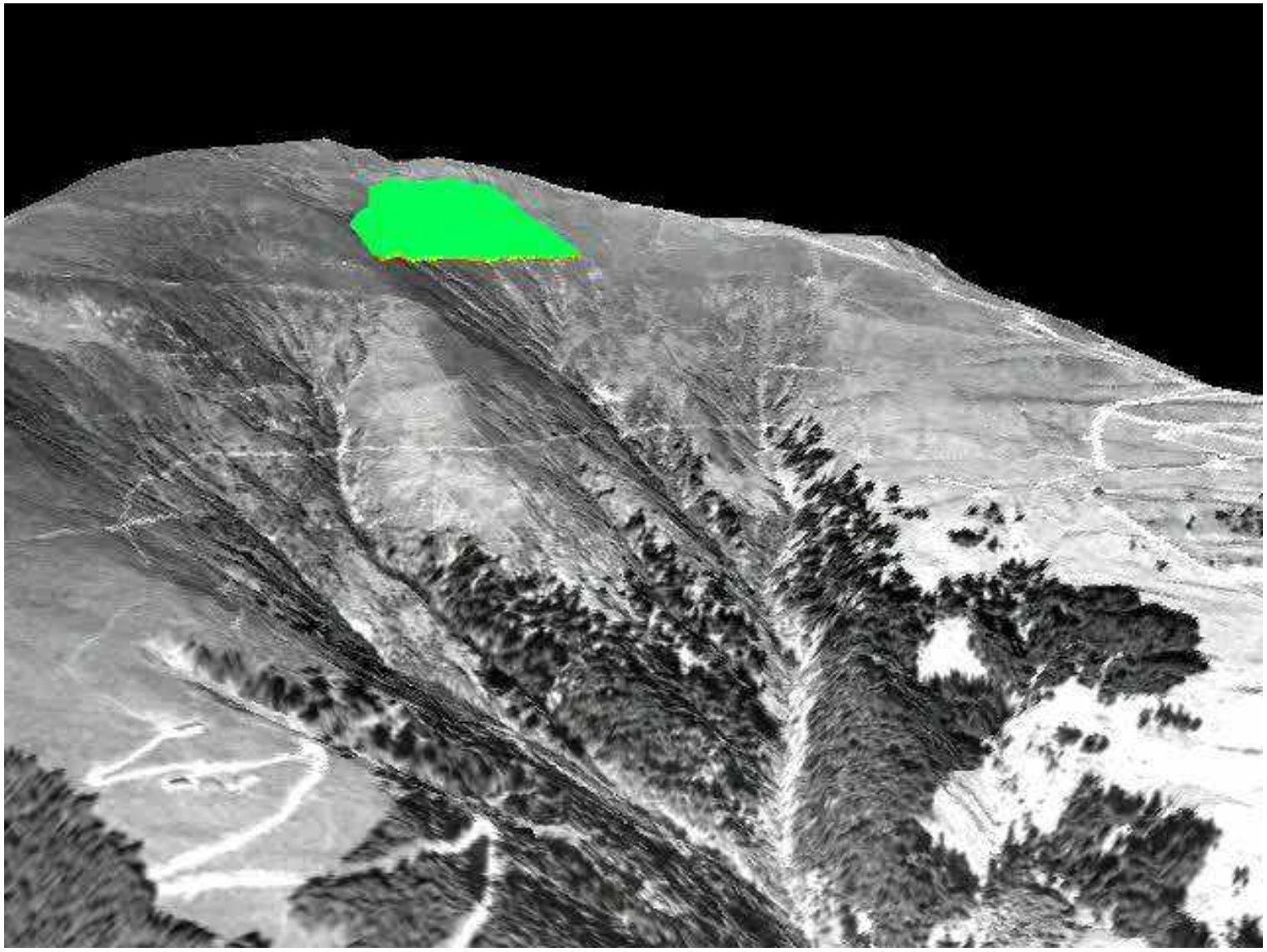
flow

Mudflow



Source : cUSGS

After: Sudibyakto , June 2005



After: Ulrik Domaas, NGI,2005

General Characteristics of Landslide in Thailand

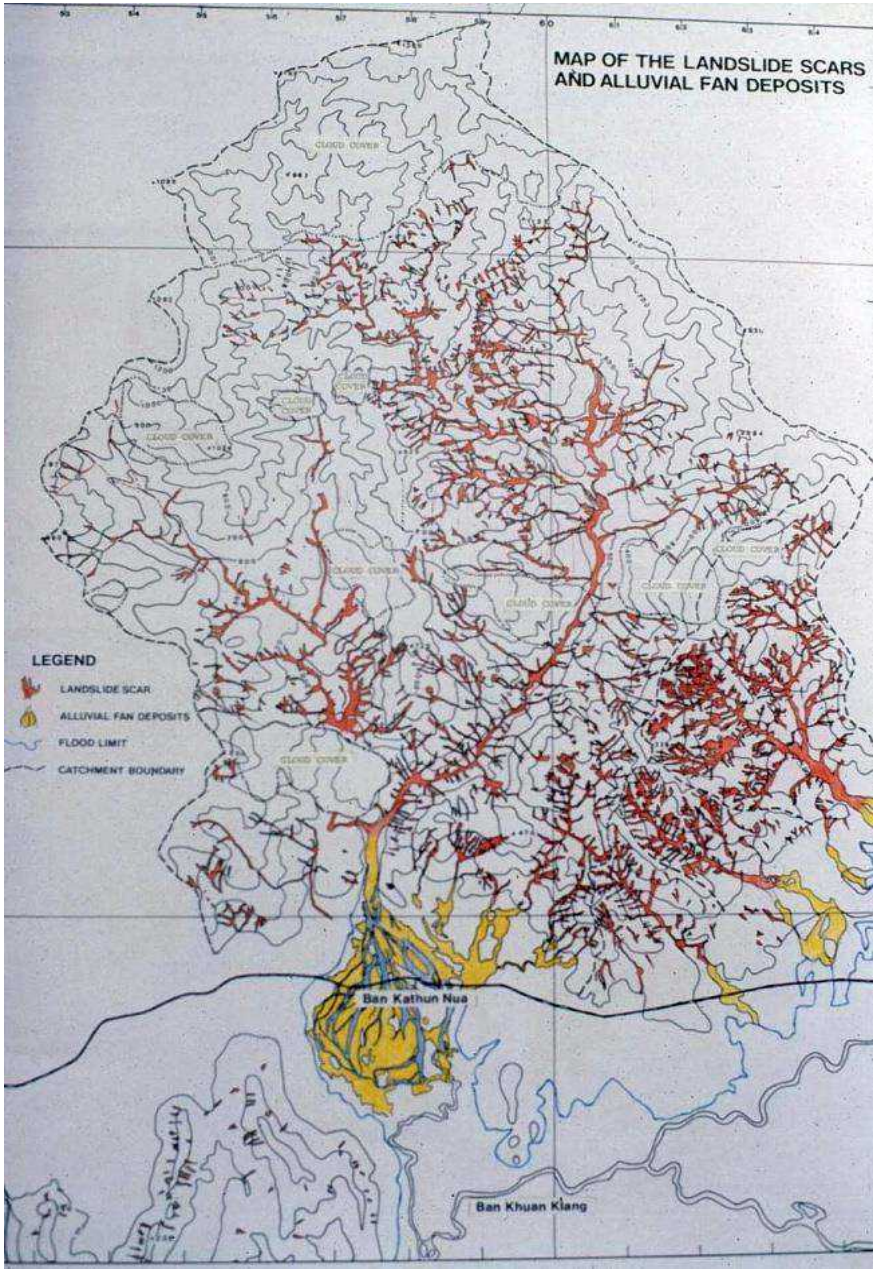
Landslide types were mainly flows type

- **Debris avalanches**
- **Gully erosions**
- **Earth flows**

Large landslide events

22 November 1988

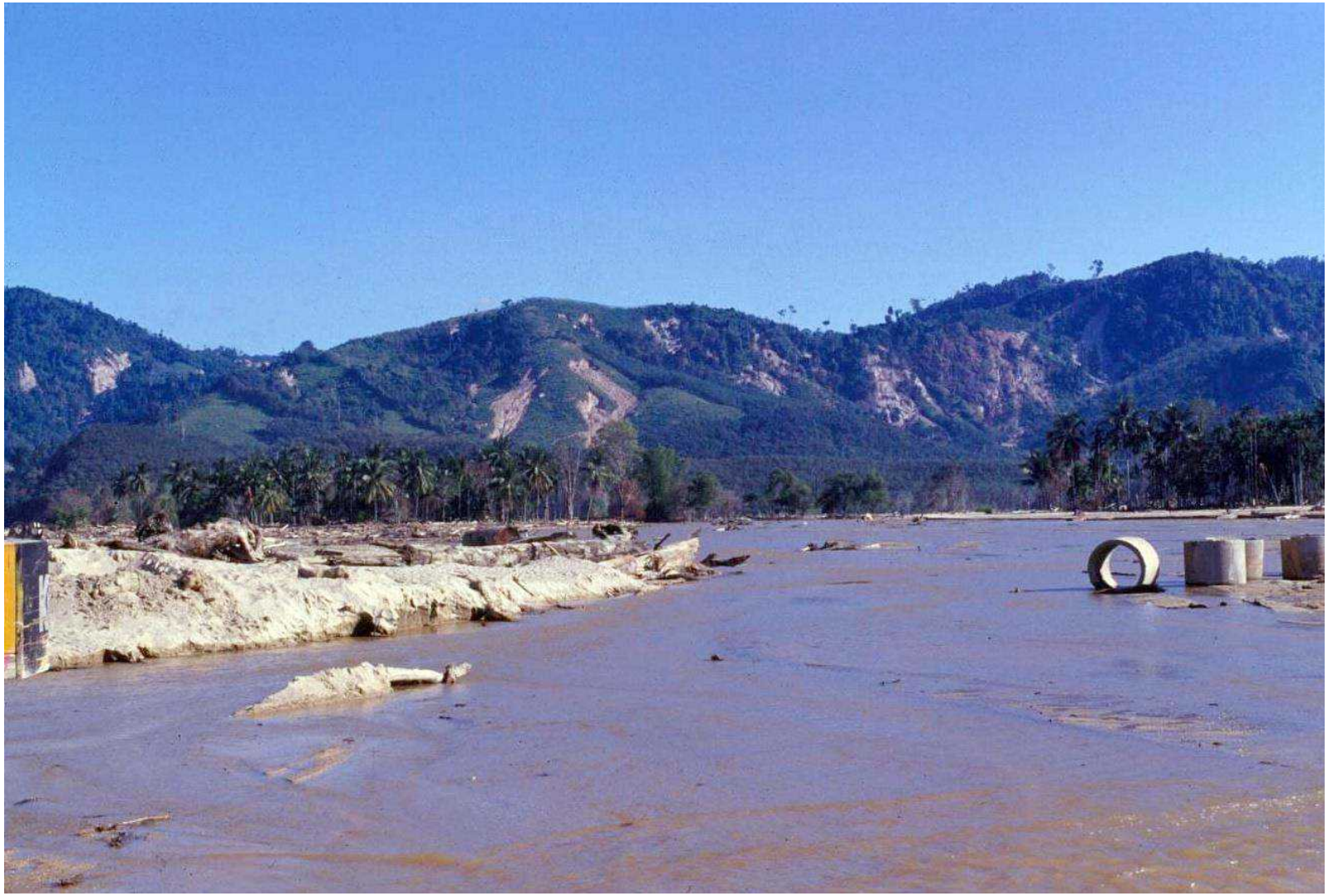
Ban Kathun Nua, Pipoon District, Nakhon Si Thammarat Province: more than 230 persons were killed and injured, 1,500 houses were damaged, Total damage cost is around 1,000 million Baht



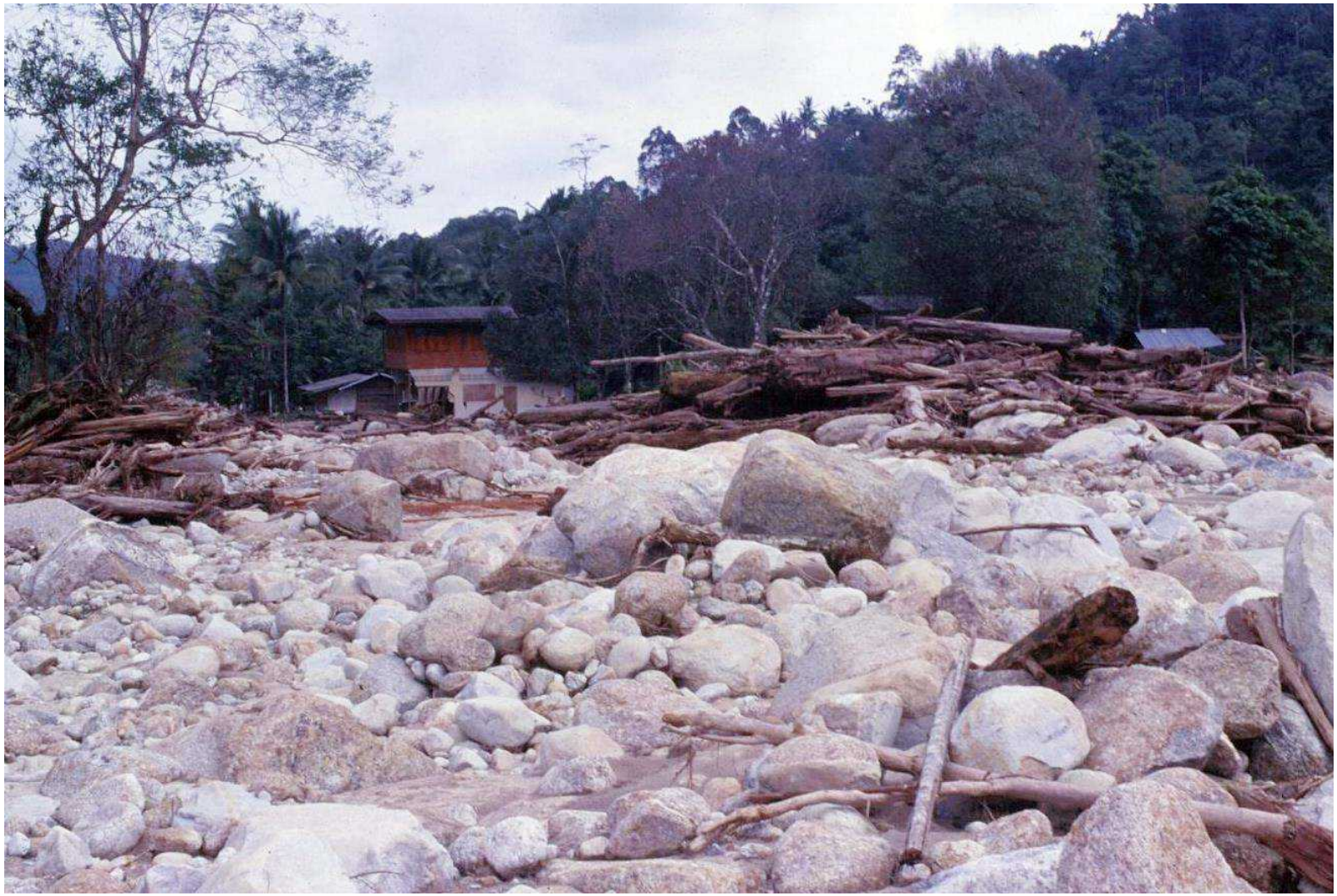
Ban Kathun Nua
22 November 1988
Map of landslide scars

Air-photo interpretation

Ban Kathun Nua



Ban Kathun Nua



Large landslide events

11 August 2001

Ban Nam Ko, Lomsak District, Phetchabun Province

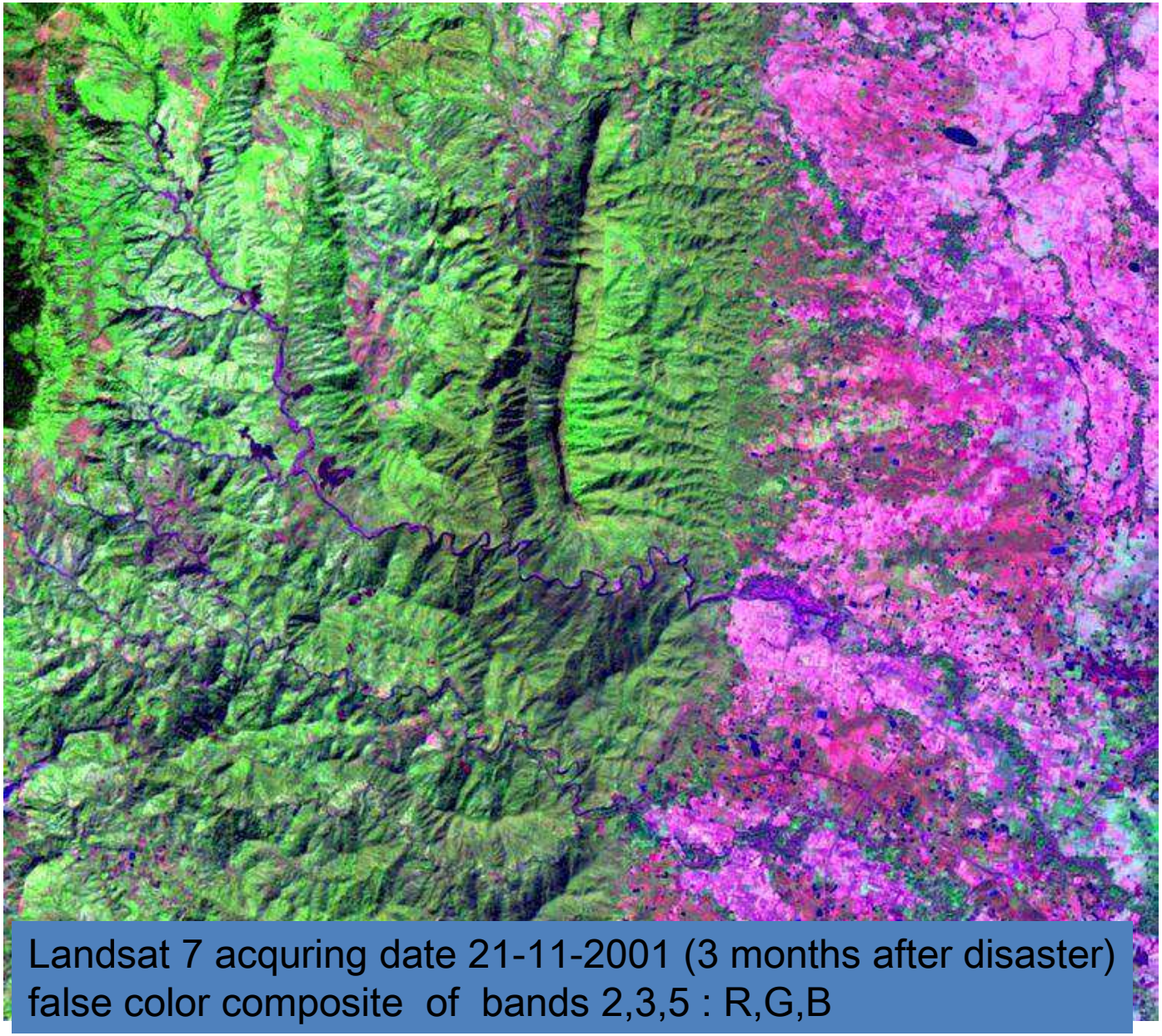
136 casualties, 109 injures, 4 missing, 188 destroyed houses and 645 million Baht of total damage

Ban Nam Ko

Ban Nam Ko

Ban Nam Ko

Ban Nam Ko



Landsat 7 acquring date 21-11-2001 (3 months after disaster)
false color composite of bands 2,3,5 : R,G,B

Large landslide events

83 casualties, 33 missing, 673 destroyed houses and 308 million Baht of total damage

23 May 2006

Labrae, Thapra and Muang District, Uttaladit Province, Srisatchanalai District, Sukhothai Province, Muang District, Phrae Province

Uttaladit

Uttaladit

Qualitative Landslide Hazard Model

H = SUSCEPTIBILITY * TRIGGER (after Mora & Vahrson)

- **SUSCEPTIBILITY: intrinsic susceptible factors**
  - S_R = slope
  - S_L = lithology (geology)
  - S_H = soil moisture&Land cover

- **TRIGGER:** **Combination of active driving forces & probability of occurrence**
  - T_S = seismicity
  - T_P = precipitation

Relative landslide hazard level

$$H = (S_R \times S_L \times S_H) \times (T_S + T_P)$$

After: Oddavar NGI,June 2005

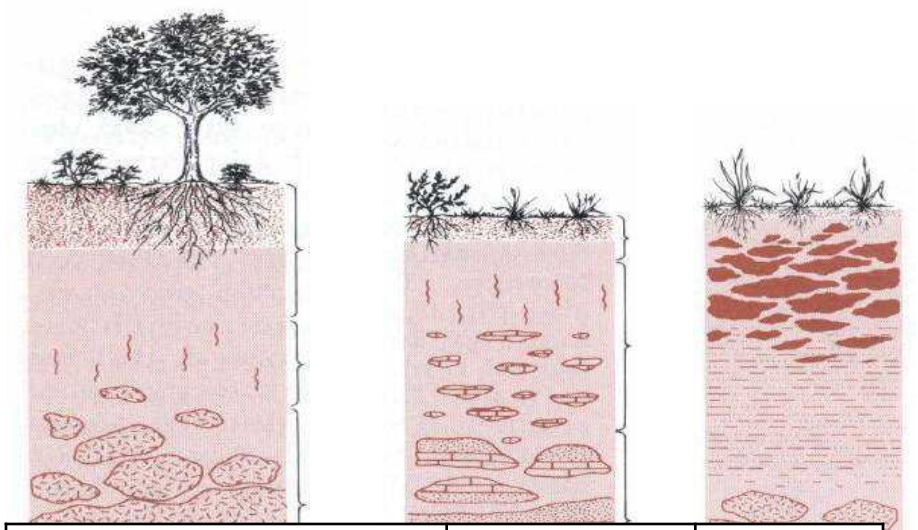
Factors Contributing to the Susceptibility

- **Topography**
  - **Slope steepness**
  - **Slope aspect**
  - **Elevation**

Factors Contributing to the Susceptibility

- **Geology**

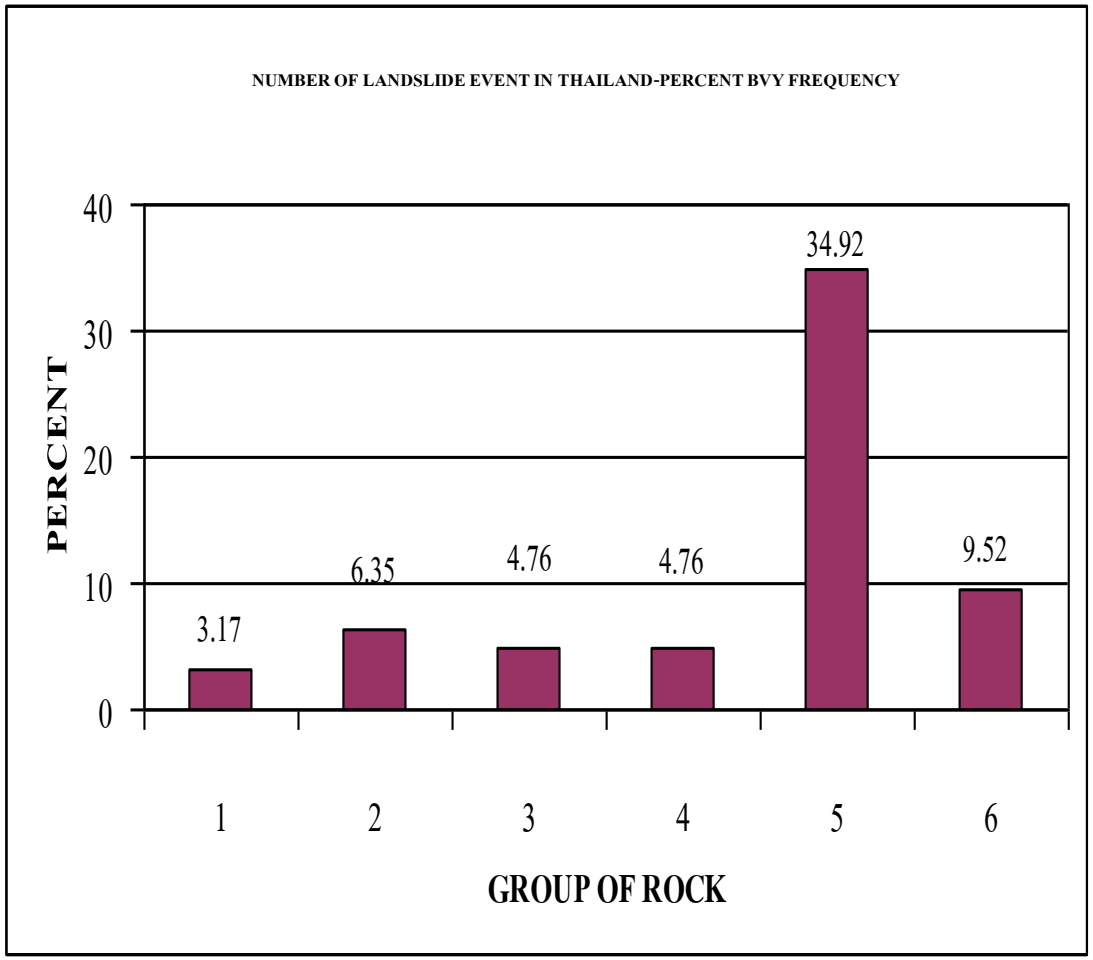
DMR applies degree of rock weathering for ranking the landslide potential



Rock type	Landslide potential	Rating
Limestone, dolomite	Low	0-1
Quartzite, sandstone	Middle	1
Shale, Slate, Phyllite, Schist	High	2
Granite, Gniest, Volcanic	Very high	3-4

Lithology(Geology)

Percent of landslide events in each rock groups in Thailand



1: Carboniferous -Permian granite

2: Jurassic-Cretaceous granite

3: Jurassic granite

4: Volcanic rock and other intrusive rocks

5: sedimentary rocks

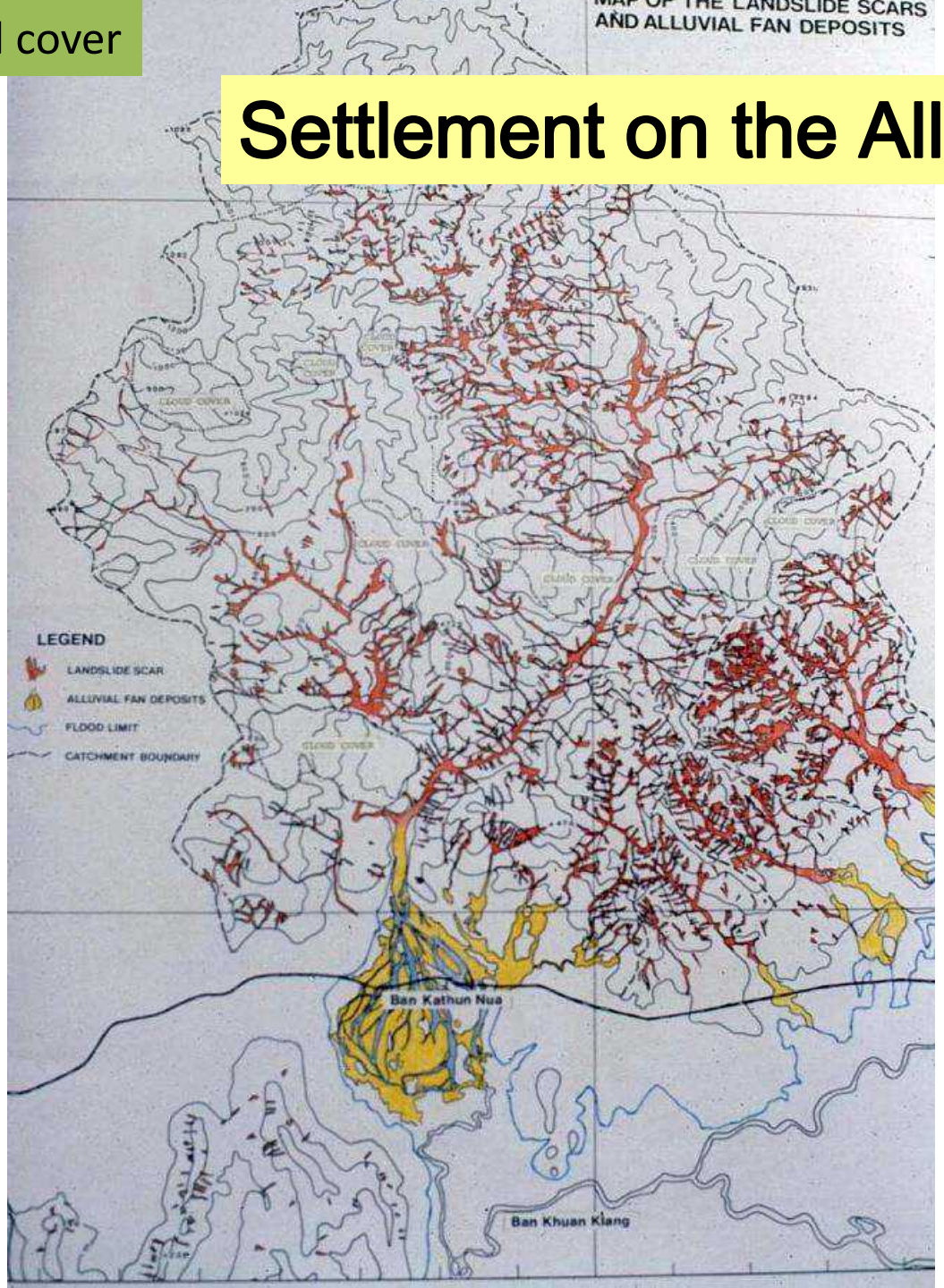
6 Metamorphic rocks

7: Quaternary sediments

8: Limestone

Soil moisture&Land cover

Settlement on the Alluvial Fan



Trigger Factors

- Earth Quake
- Heavy Rain

Earth Quake

Las Colinas Landslide El Salvador, 2001 (Earthquake magnitude 7.6)

At least 844 people killed, 4,723 injured, 108,226 houses destroyed and more than 150,000 buildings damaged in El Salvador. About 585 of the deaths were caused by large landslides in Nueva San Salvador and Comasagua. Utilities and roads damaged by more than 16,000 landslides.

http://neic.usgs.gov/neis/eq_depot/2001/eq_010113

After: Oddavar NGI,June 2005

Earth Quake

Landslide trigger by earthquake Eastern Sichuan , CHINA May 12,2008 ,M.7.9

At least 69,195 people killed, 374,177 injured and 18,392 missing and presumed dead in the Chengdu-Lixian-Guangyuan area. More than 45.5 million people in 10 provinces and regions were affected. At least 15 million people were evacuated from their homes and more than 5 million were left homeless. An estimated 5.36 million buildings collapsed and more than 21 million buildings were damaged in Sichuan and in parts of Chongqing, Gansu, Hubei, Shaanxi and Yunnan. The total economic loss was estimated at 86 billion US dollars. Beichuan, Dujiangyan, Wuolong and Yingxiu were almost completely destroyed. Landslides and rockfalls damaged or destroyed several mountain roads and railways and buried buildings in the Beichuan-Wenchuan area, cutting off access to the region for several days. At least 700 people were buried by a landslide at Qingchuan. Landslides also dammed several rivers, creating 34 barrier lakes which threatened about 700,000 people downstream. A train was buried by a landslide near Longnan, Gansu.

http://earthquake.usgs.gov/earthquakes/eqinthenews/2008/us2008ryan/#summary

Earth Quake

Landslide Trigered by 7.6 SR West Sumatra Earthquake, September 30th 2009. More than 250 people dead and burried by landslide material,

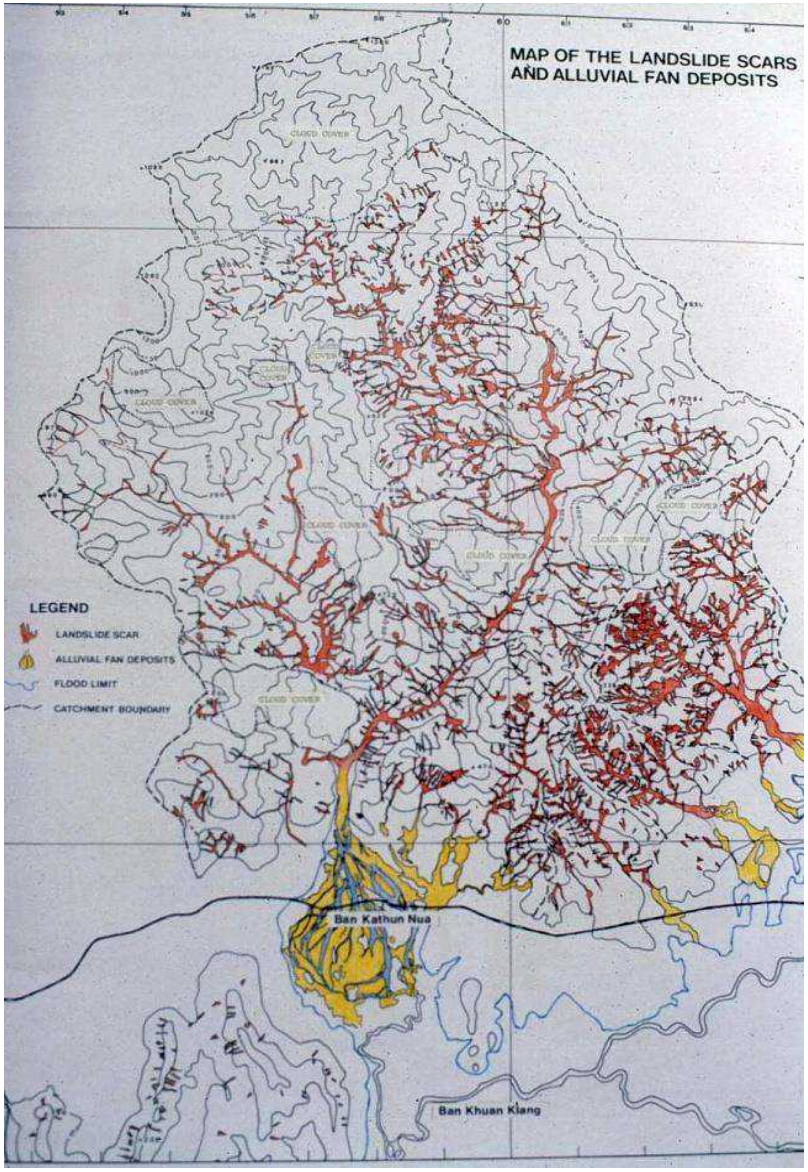
After : Surono, GAI. 2011

Heavy Rain

22 November 1988
Ban Kathun Nua, Pipoon District, Nakhon Si Thammarat Province,THAILAND

Precipitation : 442 mm in 24 hr.
700 mm in 2 days
1022 mm in 3 days

Heavy Rain



22 November 1988

Ban Kathun Nua, Pipoon District, Nakhon Si Thammarat Province

more than 230 persons were killed and injured, 1,500 houses were damaged, Total damage cost is around 1,000 million Baht

Heavy Rain

16 December 1999
Caraballeda, Venesuela

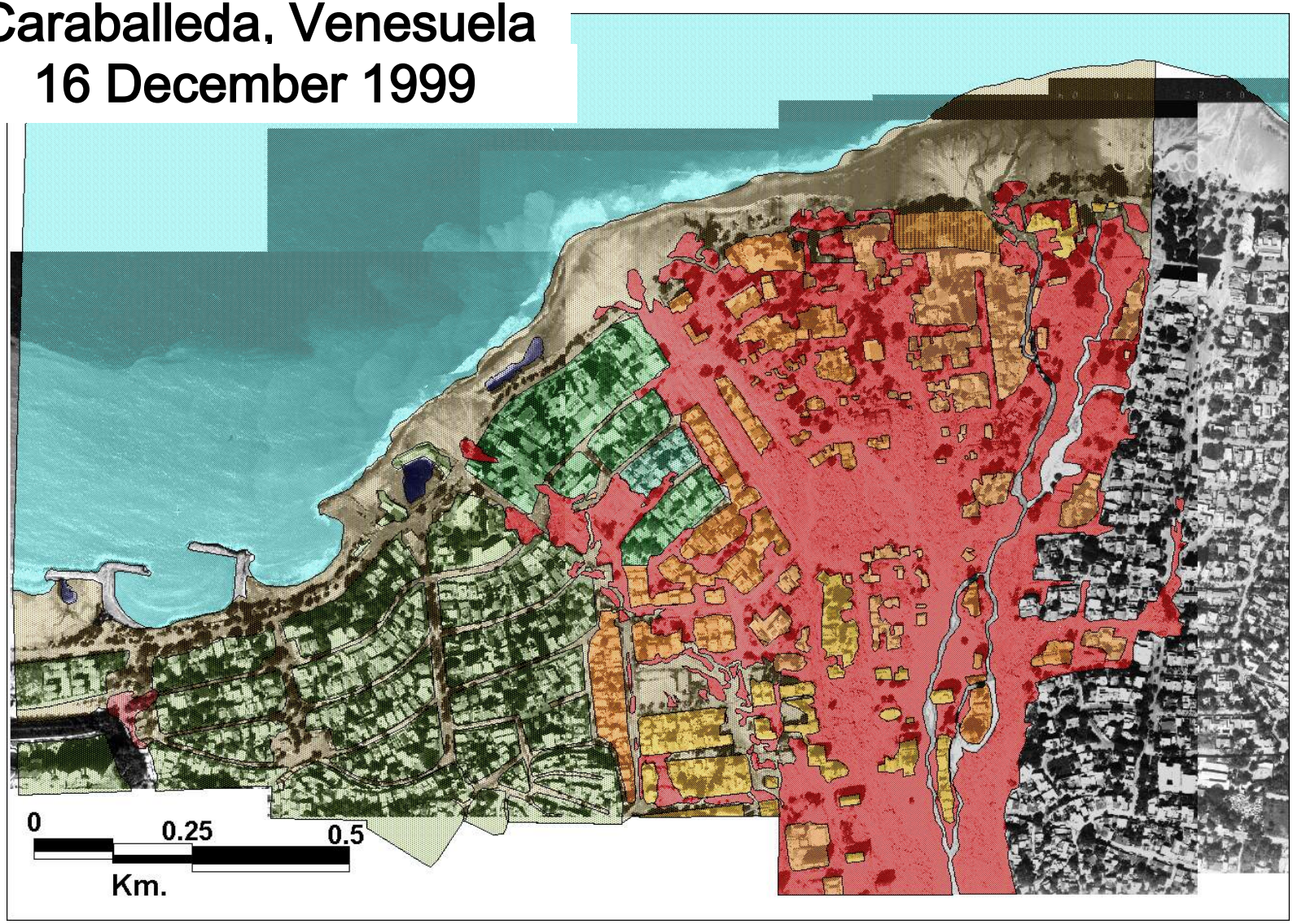
Precipitation : 410 mm in 24 hr.
791 mm in 2 days
911 mm in 3 days

Heavy Rain

Landslide in Venesuela

Heavy Rain

Caraballeda, Venesuela
16 December 1999



Heavy Rain

Caraballeda, Venesuela
16 December 1999

Earth Quake Heavy Rain

Landslide trigger by earthquake Eastern Sichuan , CHINA
May 12,2008 ,M.7.9

Earth Quake Heavy Rain

Landslide trigger by earthquake Eastern Sichuan , CHINA
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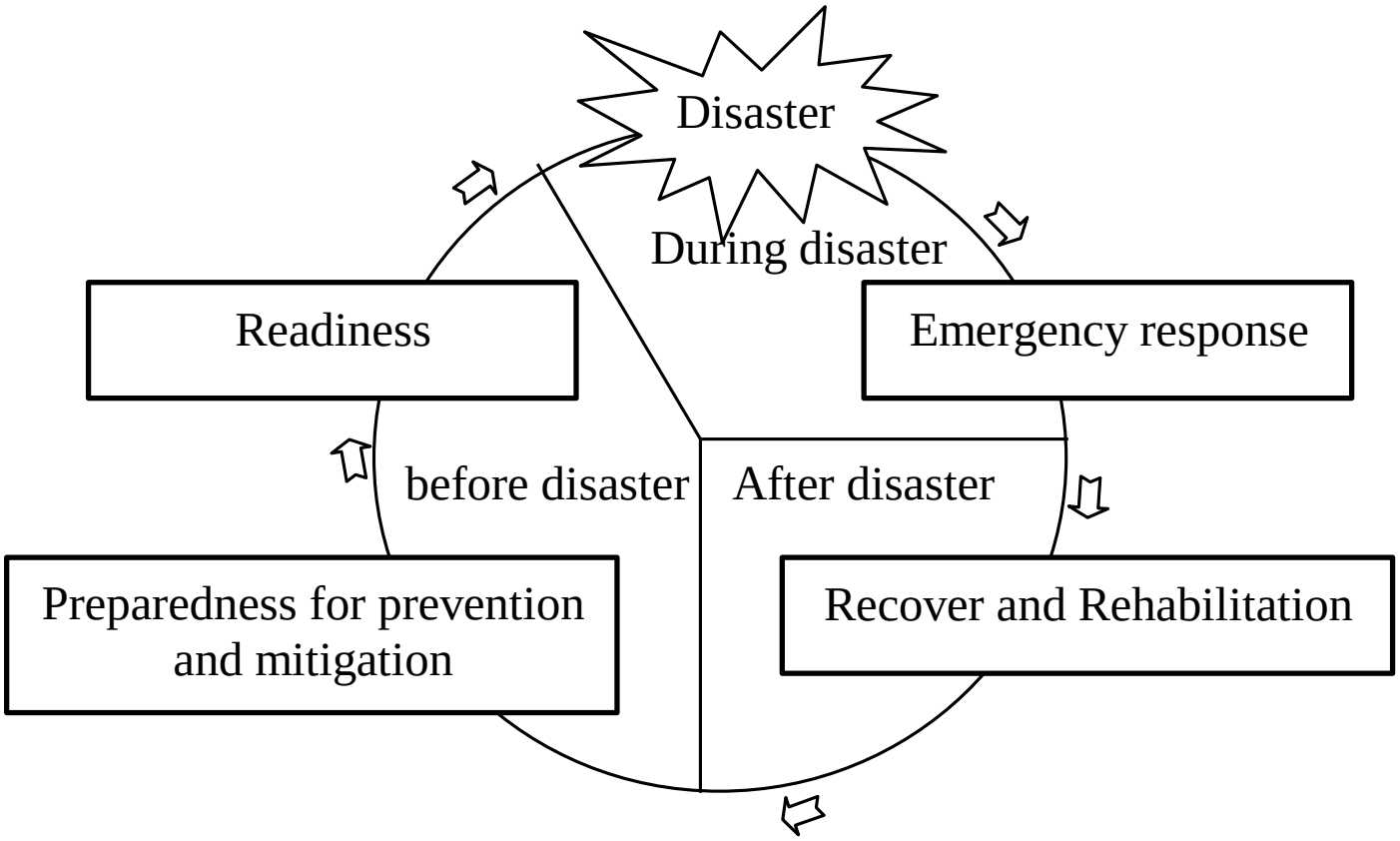
Earth Quake Heavy Rain

Landslide trigger by earthquake Eastern Sichuan , CHINA
May 12,2008 ,M.7.9

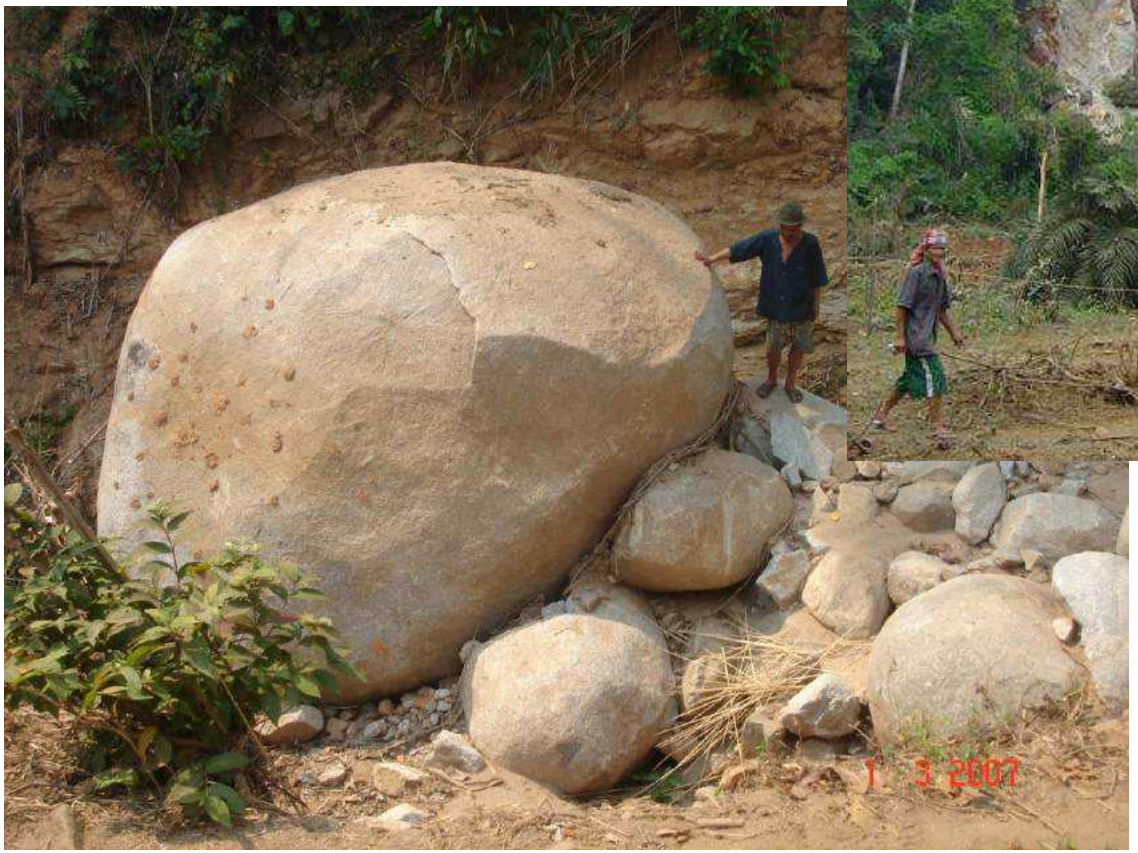
Earth Quake Heavy Rain

Landslide trigger by earthquake Eastern Sichuan , CHINA
May 12,2008 ,M.7.9

Steps of Disaster management

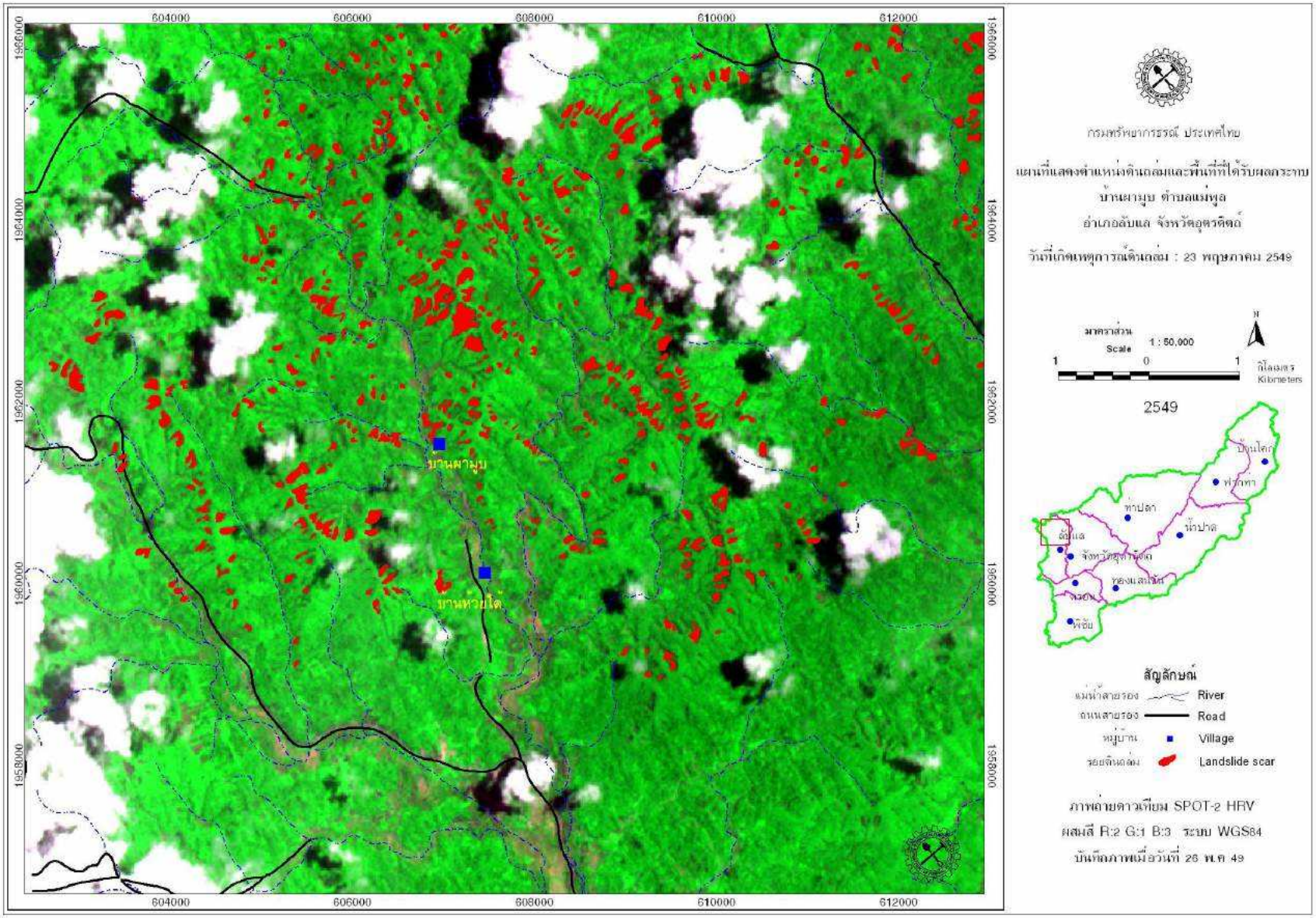


Recover and Rehabilitation

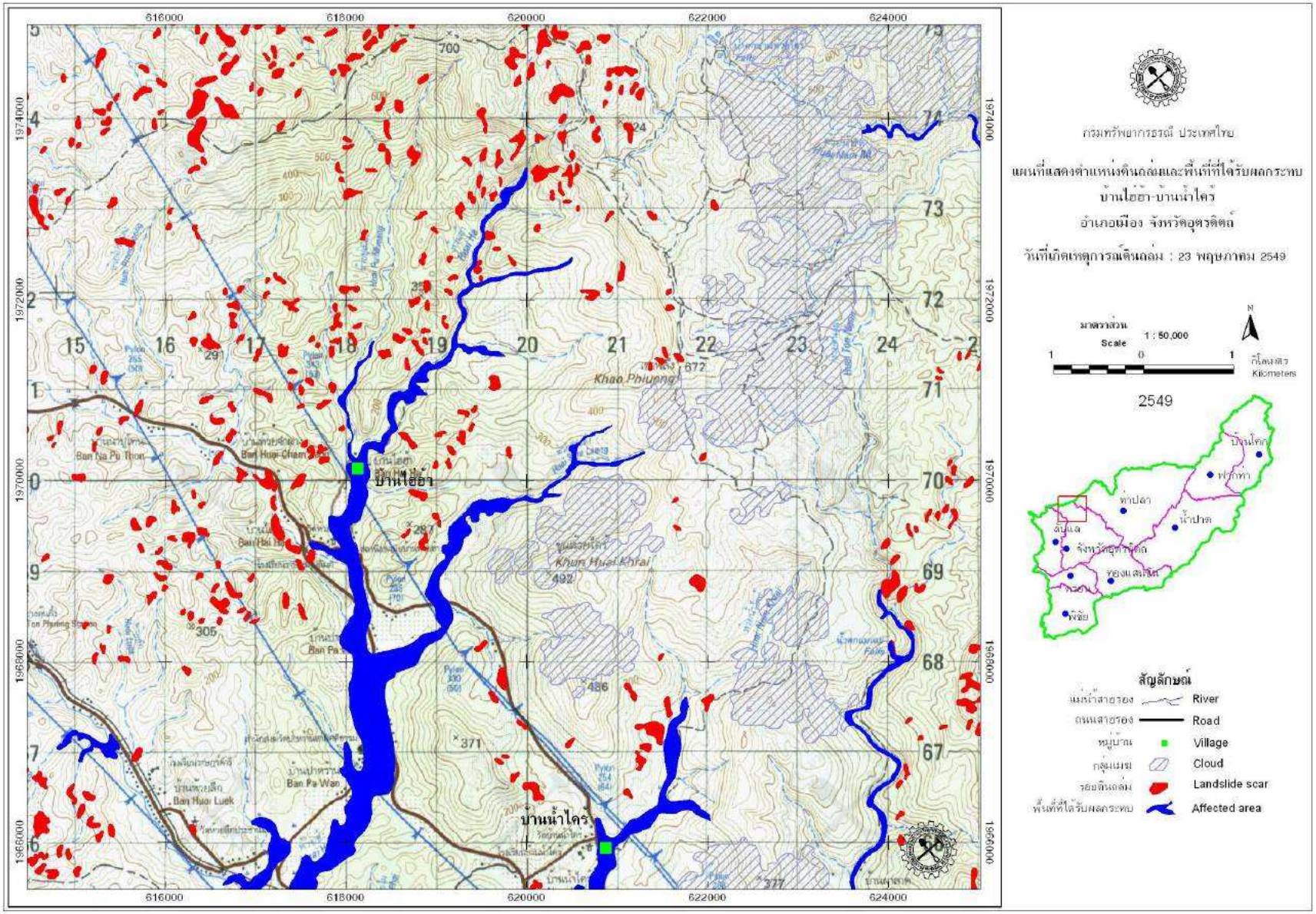


Collected fresh data from the fields

Recover and Rehabilitation



Recover and Rehabilitation



Preparedness for Prevention and Mitigation

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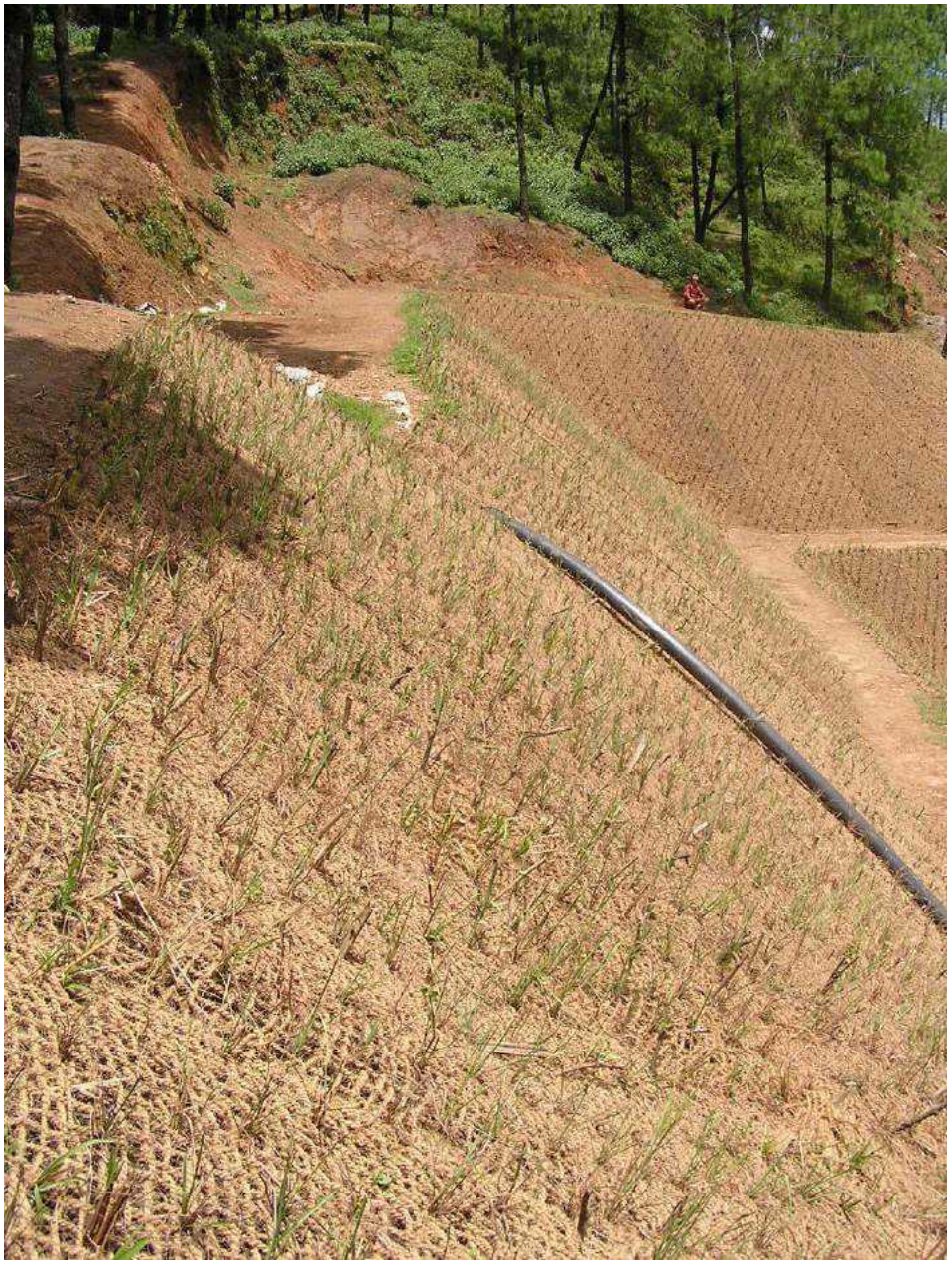
Jute netting in cut slope area-03



After: Hiruma et.al, 2005

Preparedness for Prevention and Mitigation

After: Hiruma et.al, 2005

Preparedness for Prevention and Mitigation

After: Hiruma et.al, 2005

Preparedness for Prevention and Mitigation

The Logistic Regression Equation Method is adopted.
The landslide prediction model is represented by the following equation:

Y= 1.8914-0.00281(Elevation) + 1.4215(Adjusted aspect)+ 0.00698 (Slope) + 0.00073(flow accumulation)– 0.00165(Flow direction) – 0.00505(TM 4) – 0.0042(Brightness) – 0.00504(Wetness)

And P = 1/(1+exp(-Y))

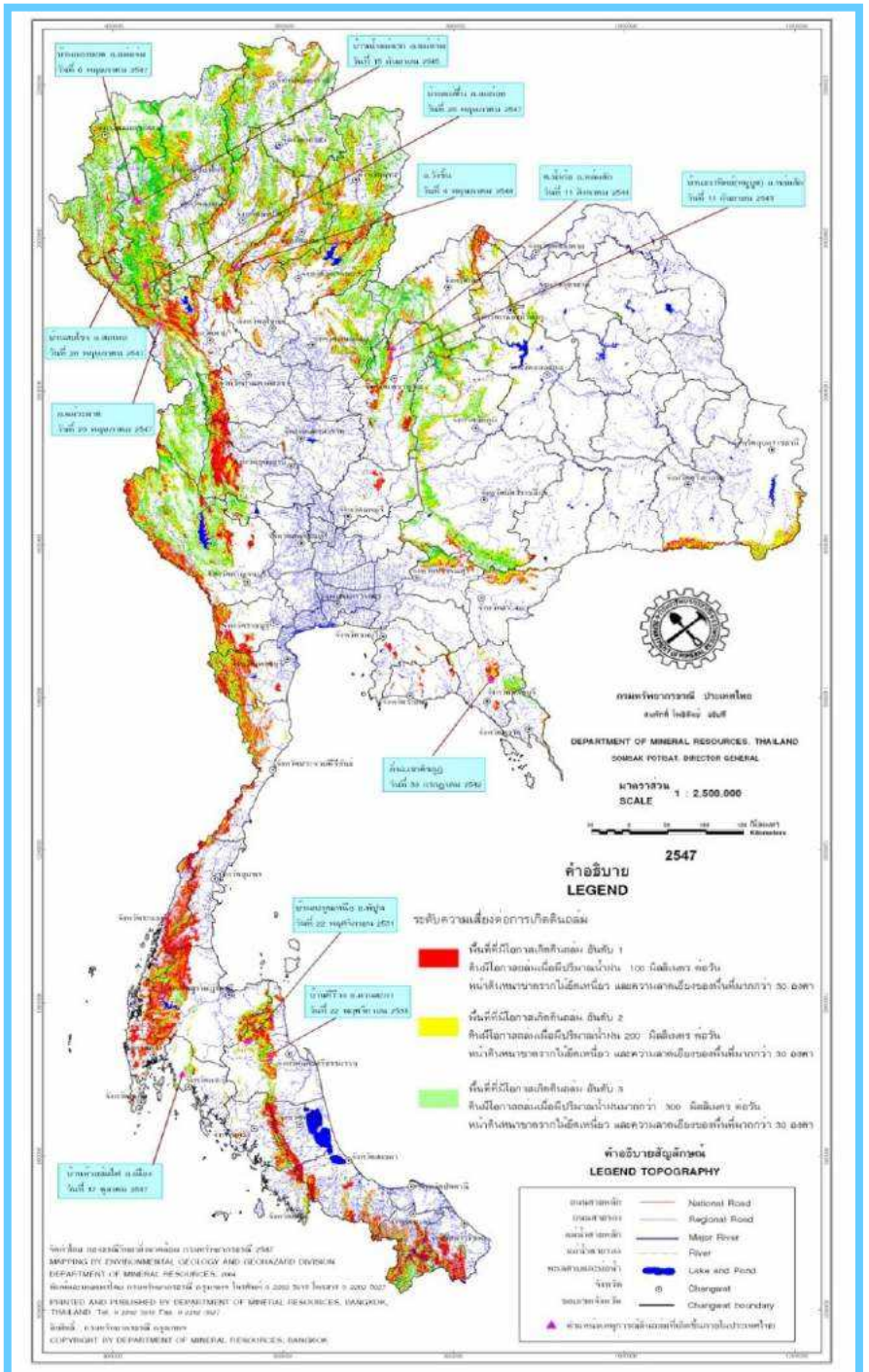
Then P = int ((p*0.67)+(geology*0.33/4)*100)

Whereas its estimated probability of landslide presence is P at any given cell.

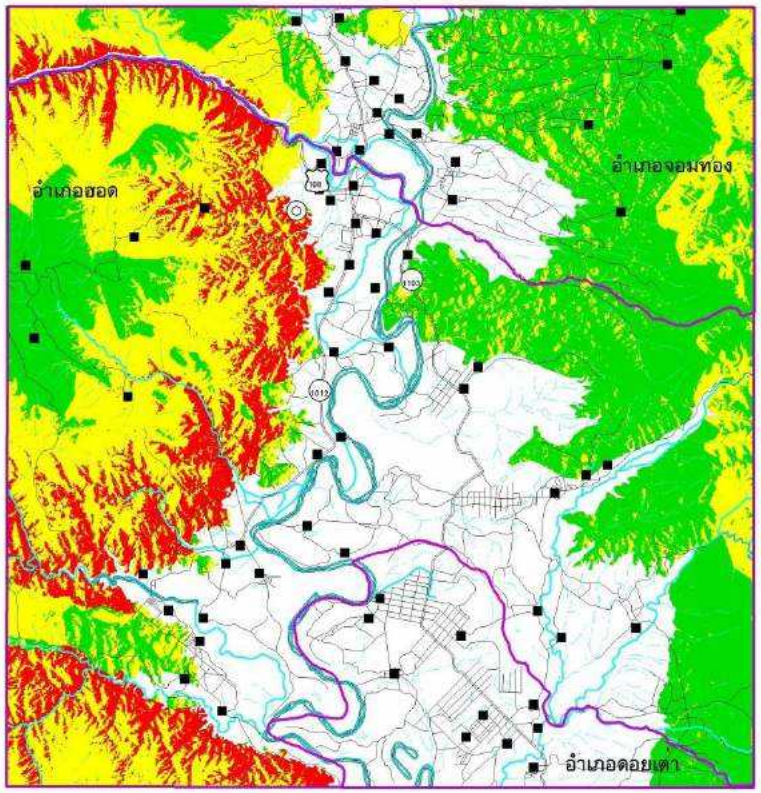
Preparedness for Prevention and Mitigation

❖ Landslide Hazard Map

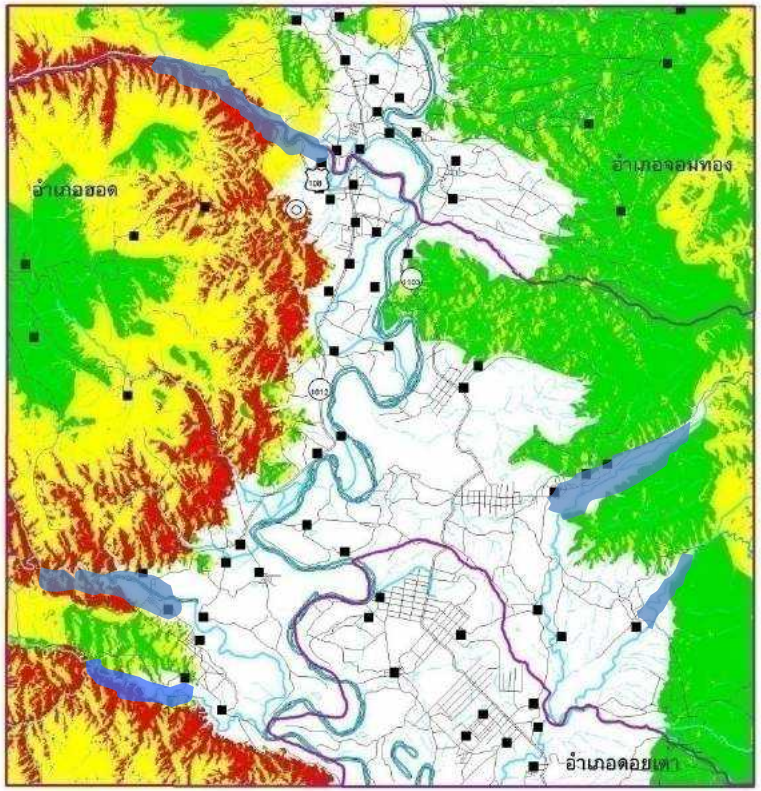
According to the study there are 2,371 villages in 51 provinces having landslide prone areas



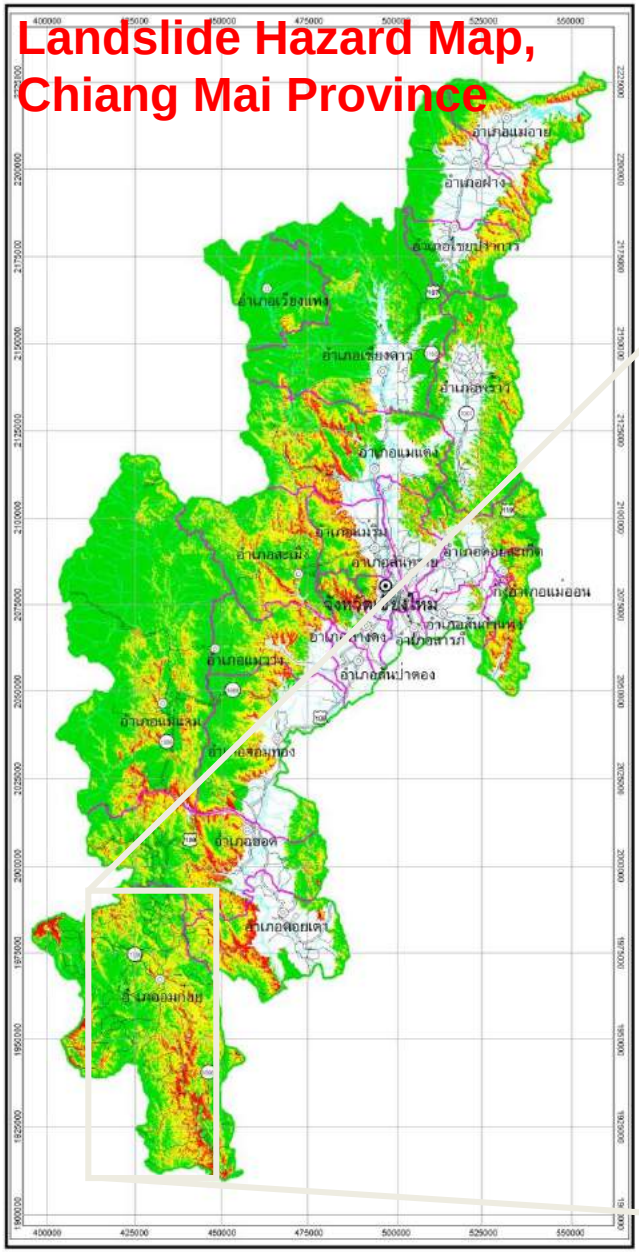
Preparedness for Prevention and Mitigation



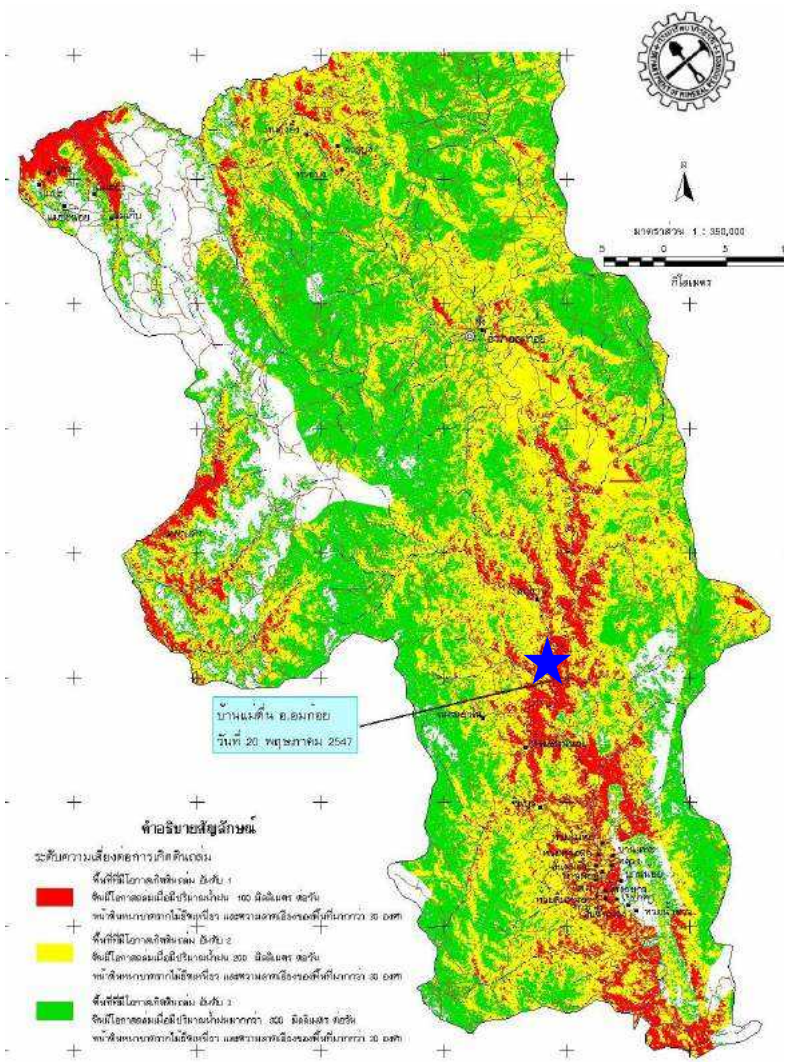
Landslide Hazard Map



Landslide Risk Map



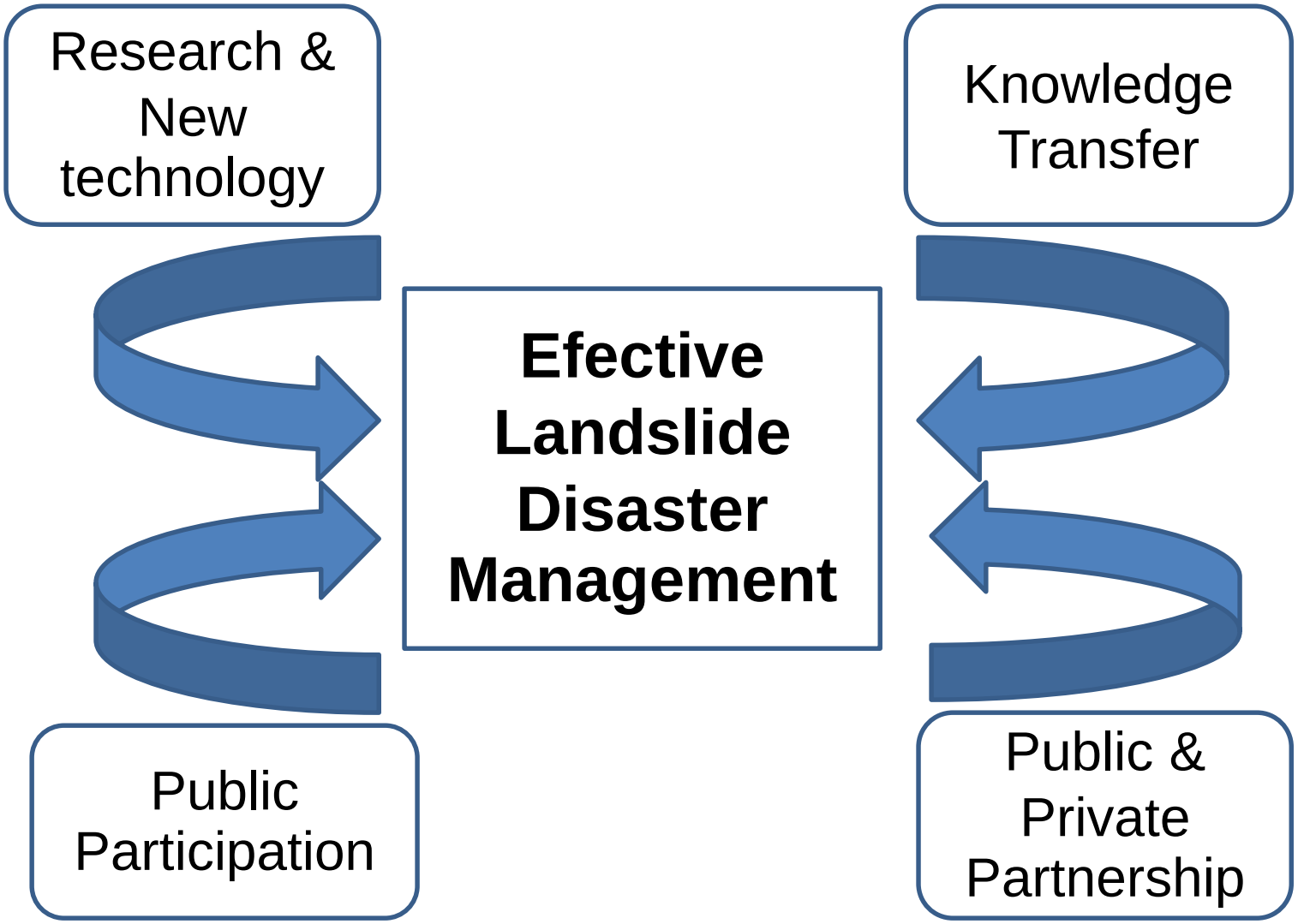
Landslide Hazard Map and Risk area in Ban Mea Toen, Omkoi District, Chiang Mai Province



Readiness

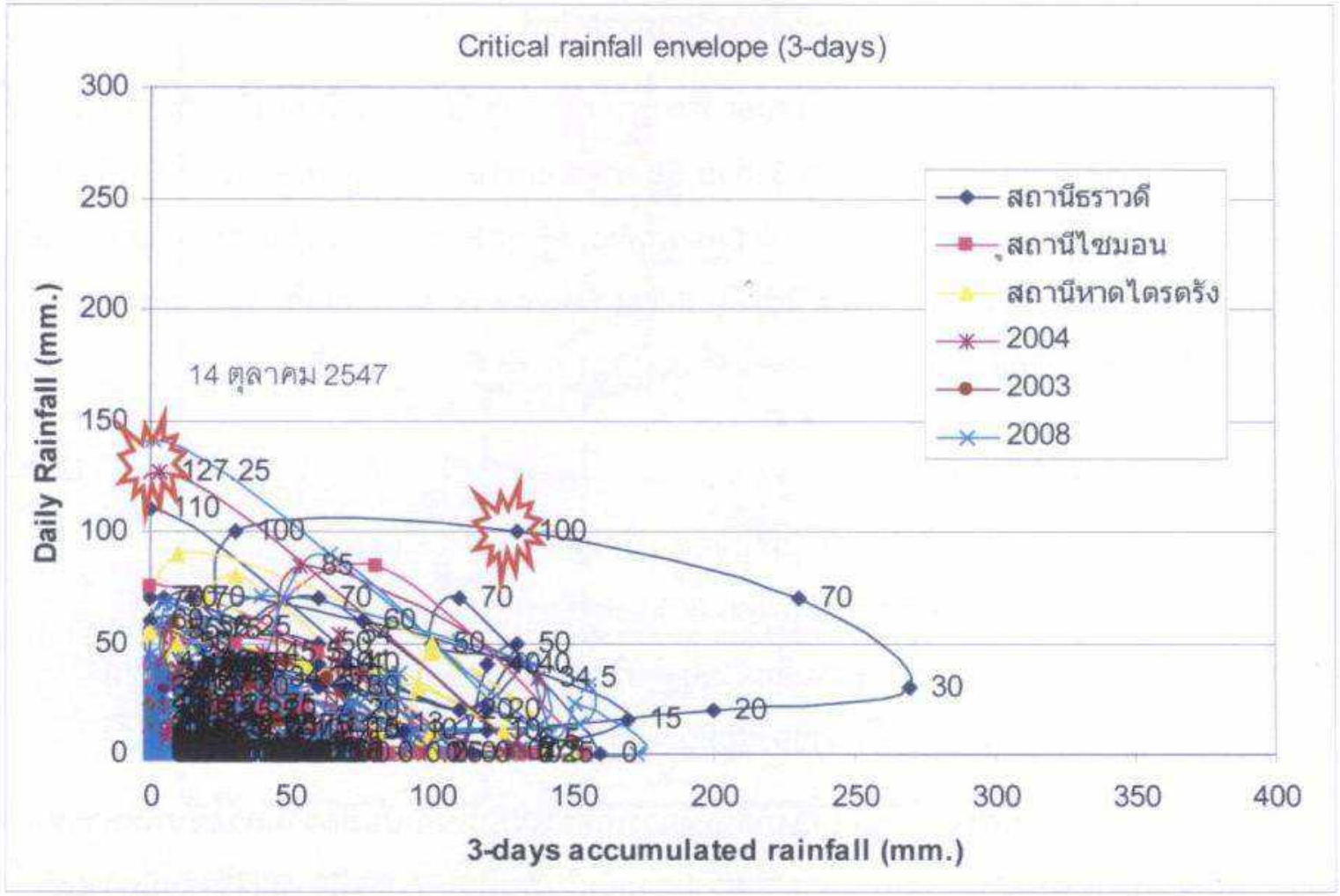
Landslide Watch Networks

Establishing their own early warning plan


Research & New technology
Knowledge Transfer
Efective Landslide Disaster Management
Public Participation
Public & Private Partnership

Thank you for your attention

Preparedness for Prevention and Mitigation



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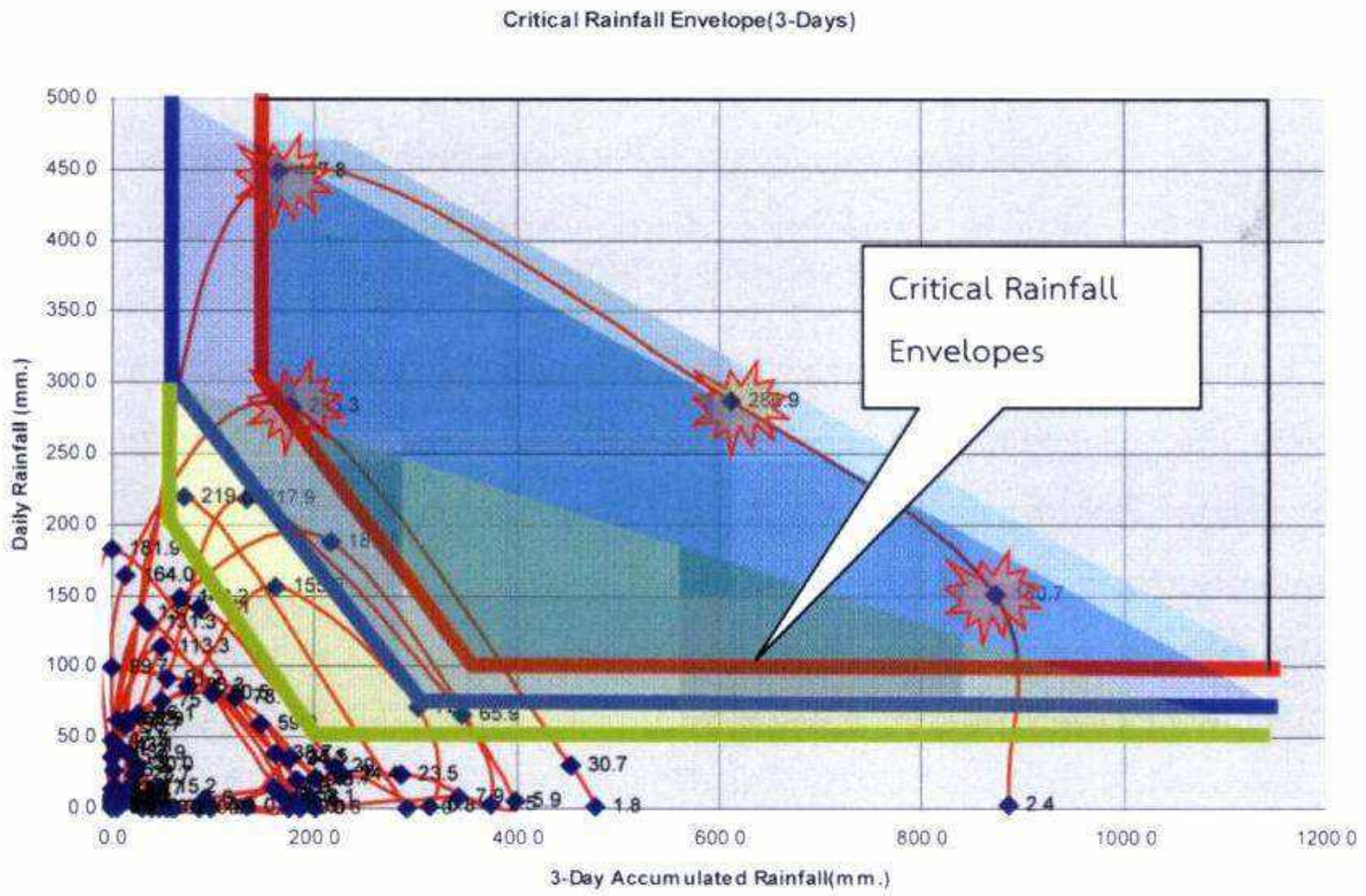

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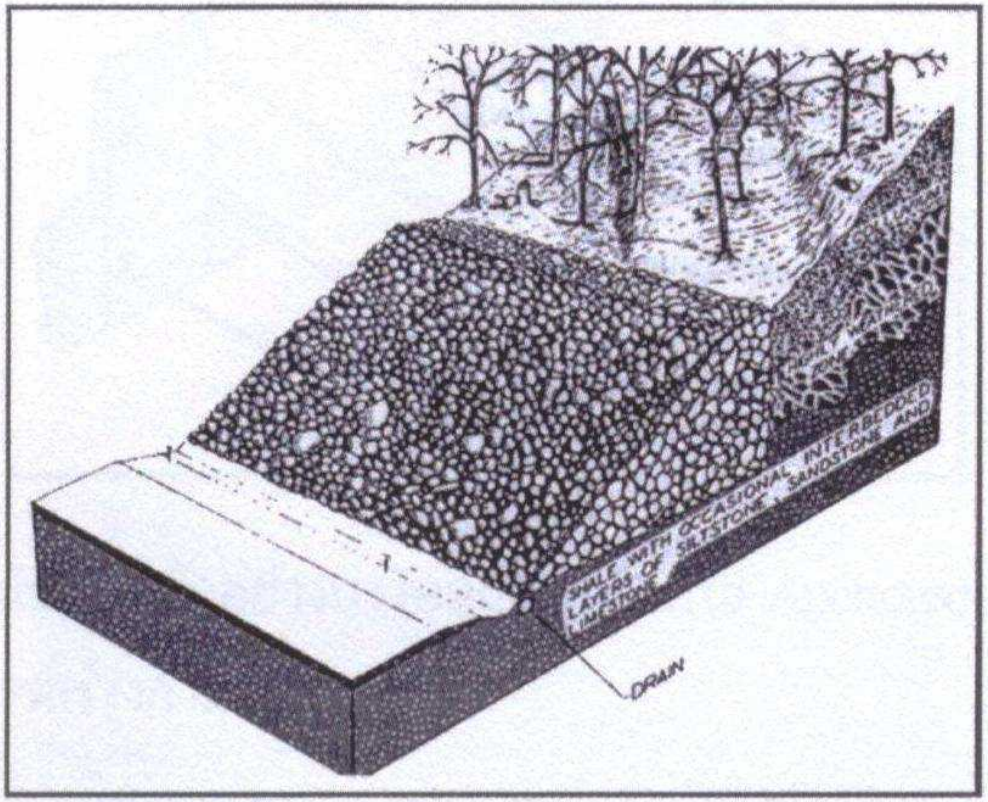

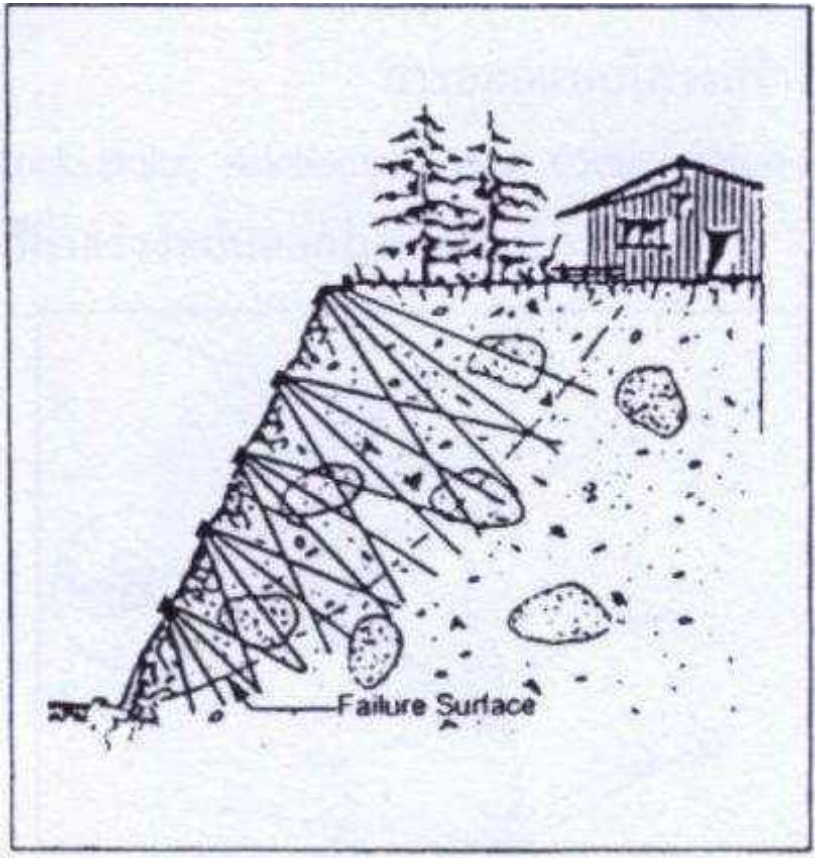

Preparedness for Prevention and Mitigation