Application of Information Technology on Disaster Risk Reduction and Emergency Preparedness

2012 International Training Workshop for Natural Disaster Reduction

Early Warning System and On-site Observation of Debris Flow Disasters

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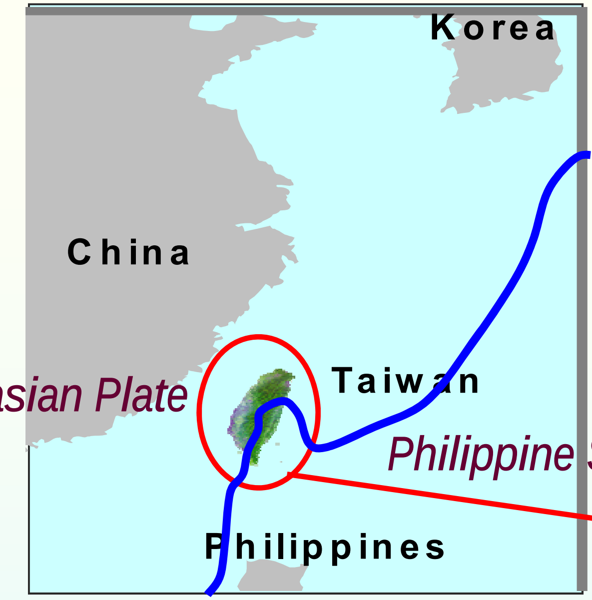
Outline

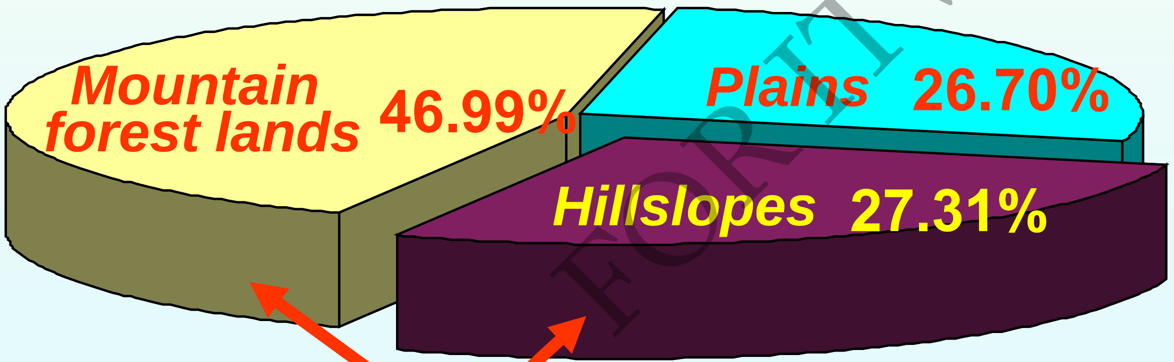
1. Background Introduction
2. Debris Flow Early Warning System
3. On-site Debris Flow Observation
4. Challenges and Future Perspective

Soil and Water Conservation Bureau (SWCB)

Introduction

Taiwan is located at the convergent boundary of the Eurasian Plate and the Philippine Sea Plate.



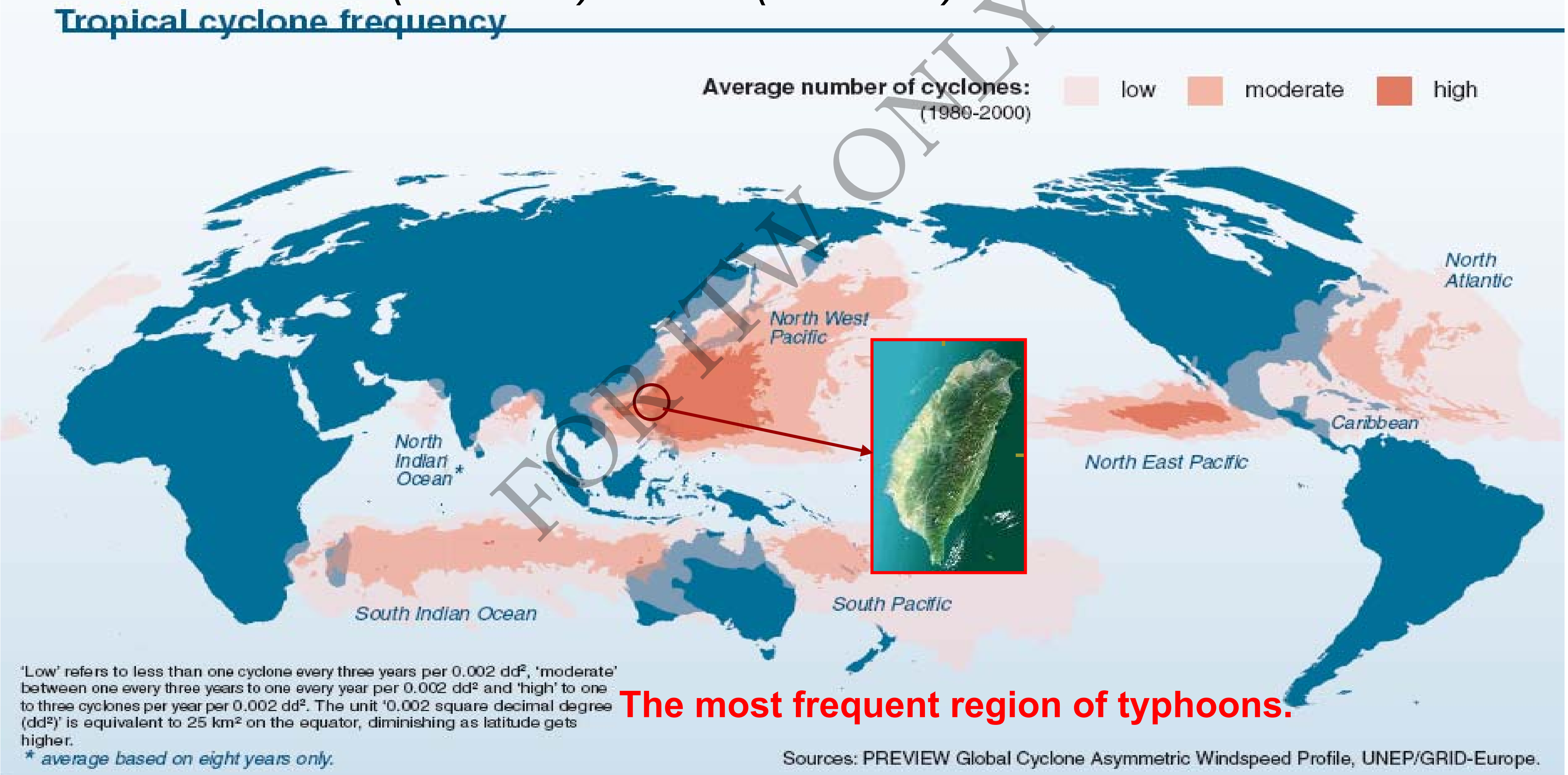


Slopelands 73.30%

Land Resources Distribution

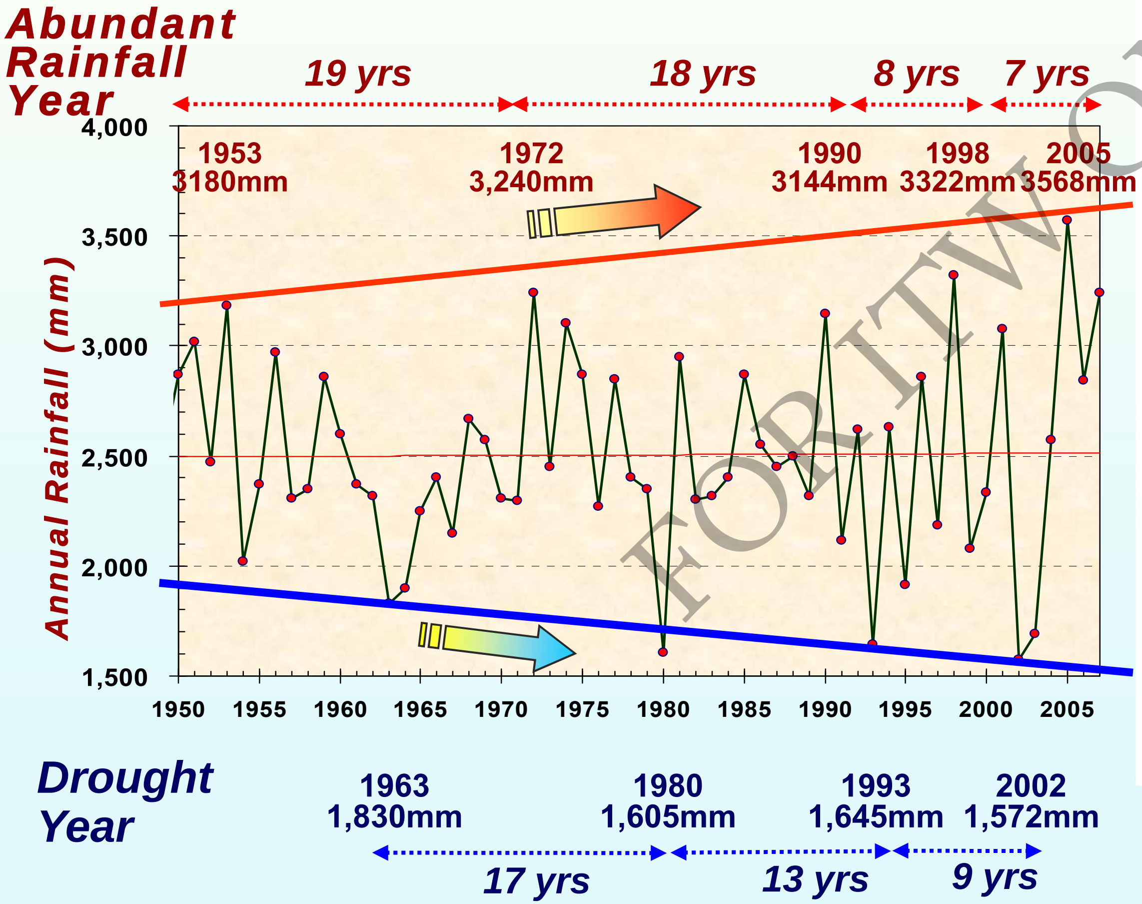
Climate Change Impact

- *Temperature increases about 1.4℃ in the last 100 years (1901-2006).*
- *Number of typhoons per year increased dramatically after 2000.*
  From N=3.2(1951-2000) to N=6.8 (2001-2009)

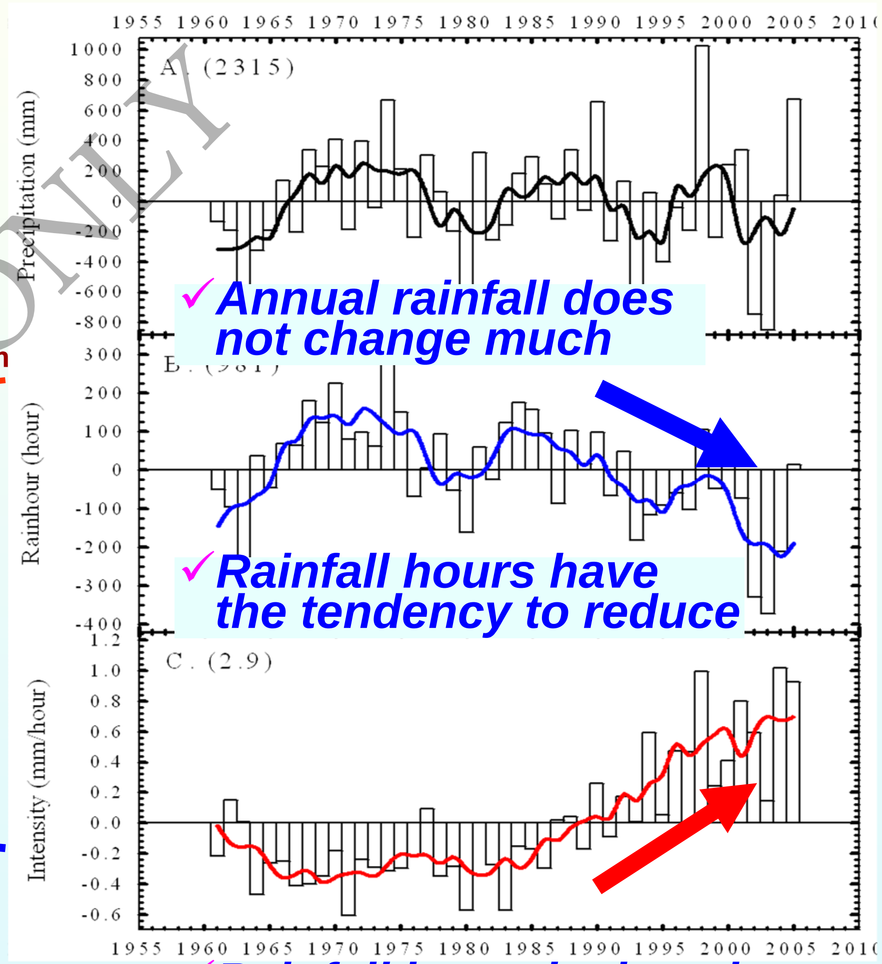


Variation of rainfall pattern of Taiwan in last 50 years

Significant change of rainfall and dry-rainy seasons increases the risk of watershed hazards.



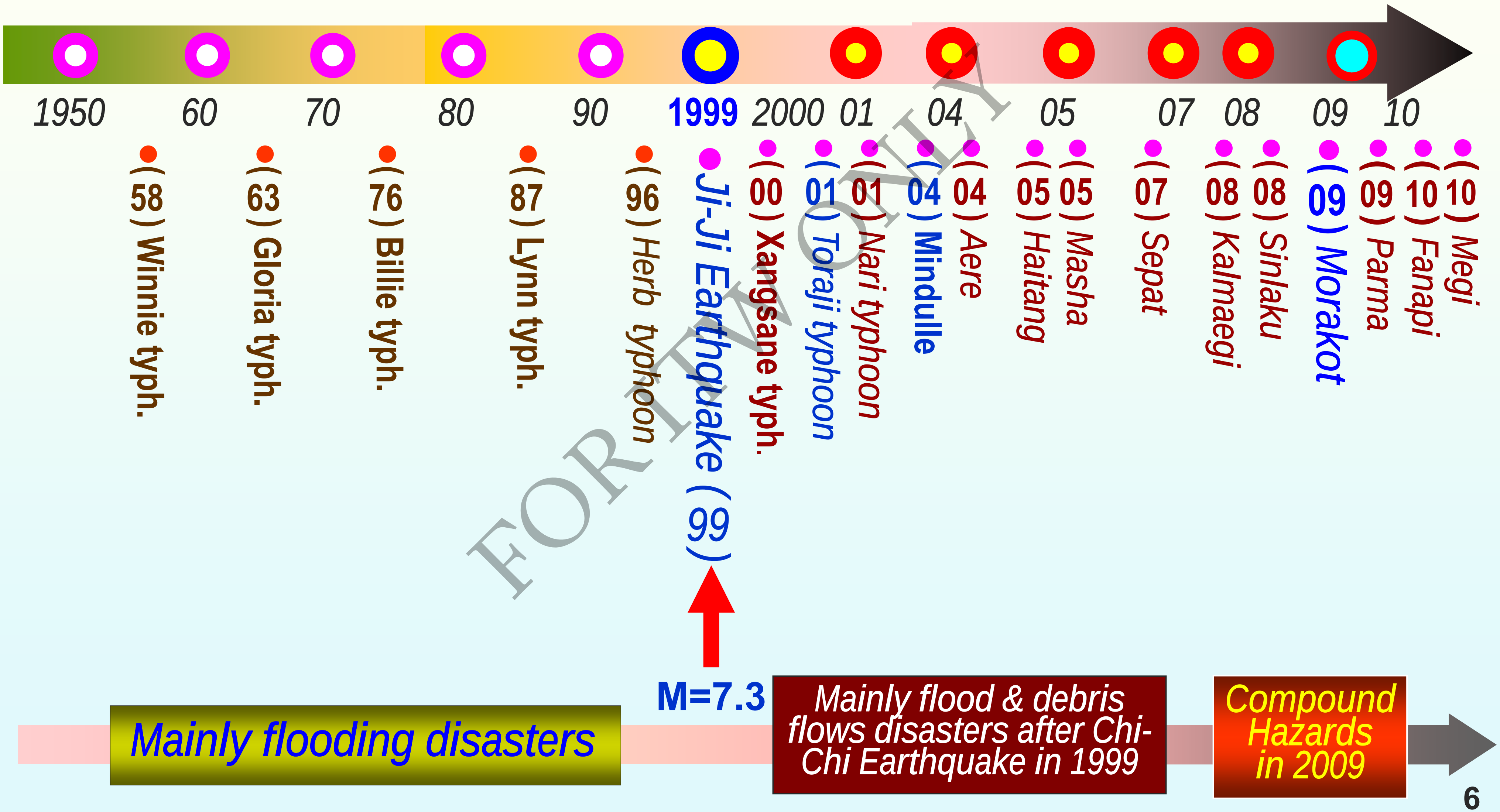
Annual rainfall of Taiwan in the past 50 years



✓Rainfall intensity has the tendency to strengthen

Data resource : WRA

Historic Typhoon Disasters in Taiwan



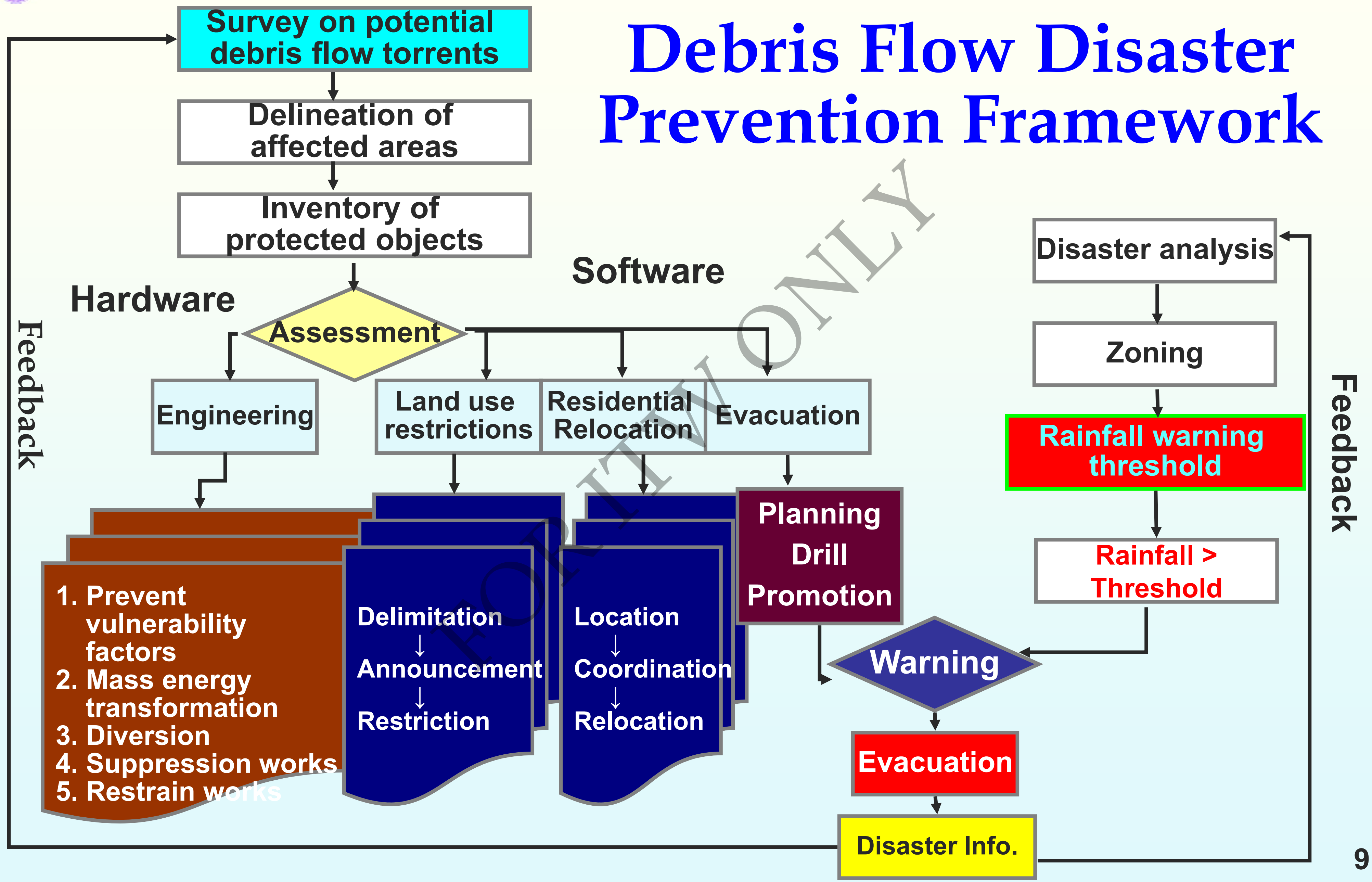
Soil and Water Conservation Bureau (SWCB)

Debris Flow Disasters in Taiwan

1996-Herb

2. Debris Flow Early Warning System

Debris Flow Disaster Prevention Framework

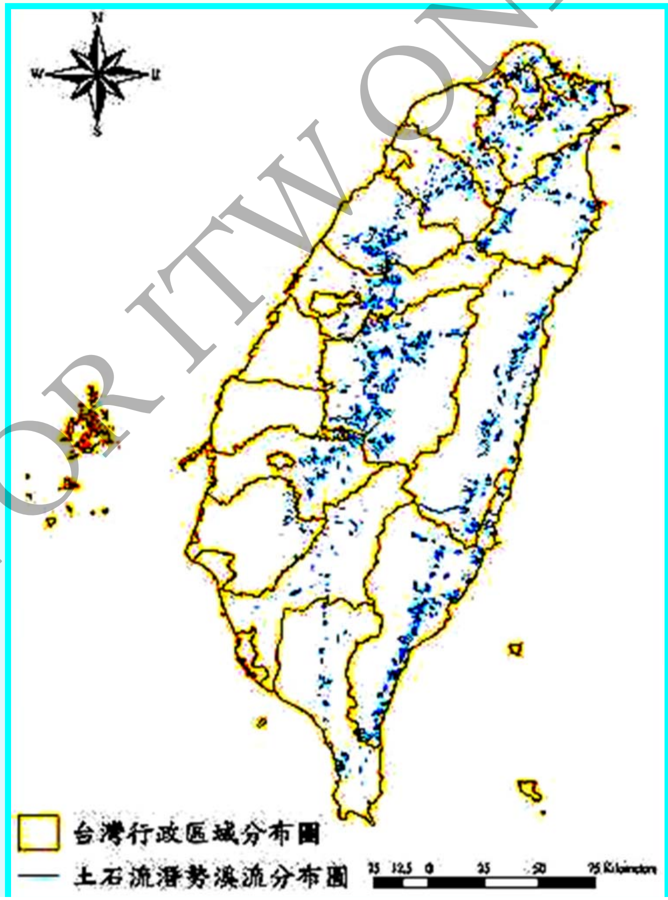


Soil and Water Conservation Bureau (SWCB)

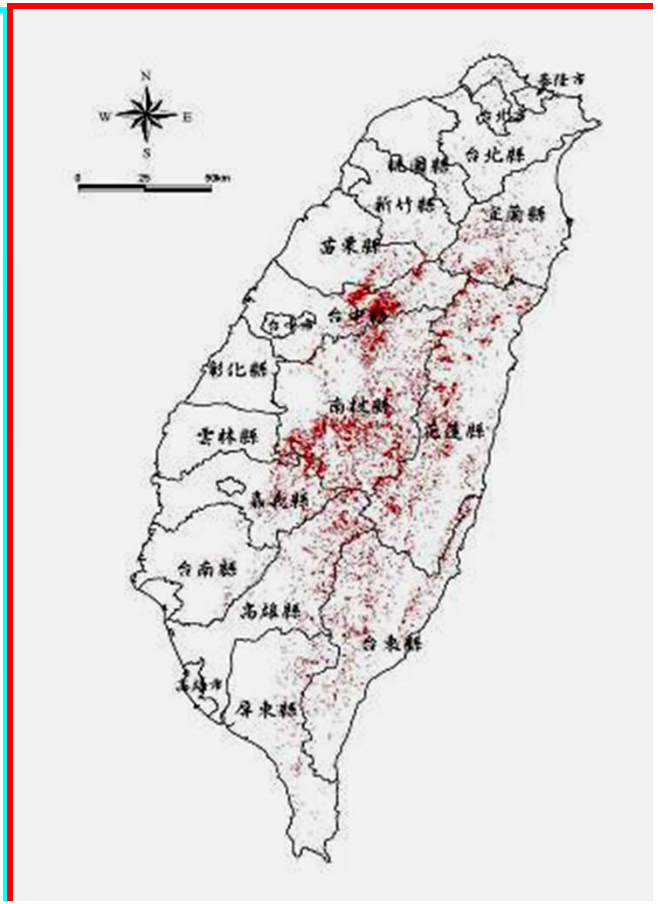
Investigation of Potential Debris Flow Torrents & Landslides

- **Potential Debris Flow Torrents**
  1,660 Torrents
- **Landslide Areas**
  46,950 ha

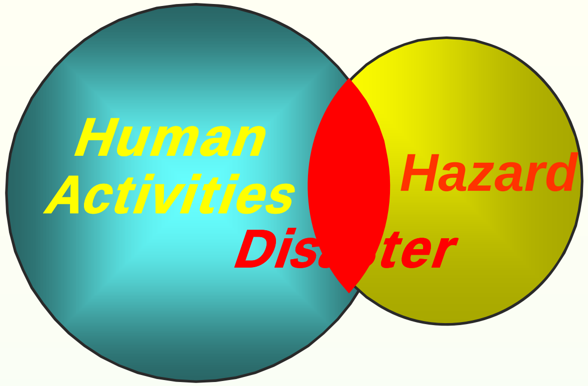
Potential Debris Flow Torrents



Historic Landslides Distribution



Investigation of Potential Debris Flow Torrents



Risk Degree=Probability X Assured Safety

Low: Risk≦46, Mid: 46<Risk<62, High: Risk≧62

Factors of Probability

- Valid watershed area：≧3 ha
  before 921 earthquake(1999) adopted 10 ha
- Rock broken extent
- Length of fault, slope…
- Upstream collapse area

Assured Safety

- Protected Targets: houses, school, roads, publics, farms…..etc.
- Including 10º slope deposit range

Risk		Probability: Low	Probability: Mid	Probability: High
Assured Safety	Low	Low	Low	High
Assured Safety	Mid	Low	Mid	High
Assured Safety	High	Mid	High	High

Risk Mapping

Debris Flow Risk Mapping

Hazard Zone Definition

High	h_{max}>2.5m $(h*v)_{max}$>2.5m²/s
Med	1m<h_{max}<2.5m 1m²/s<$(h*v)_{max}$<2.5
Low	h_{max}<1m $(h*v)_{max}$<2.5m²/s

FLO-2D debris flow simulation return period rainfall 10,100,200 years

Max velocity Distribution (v)

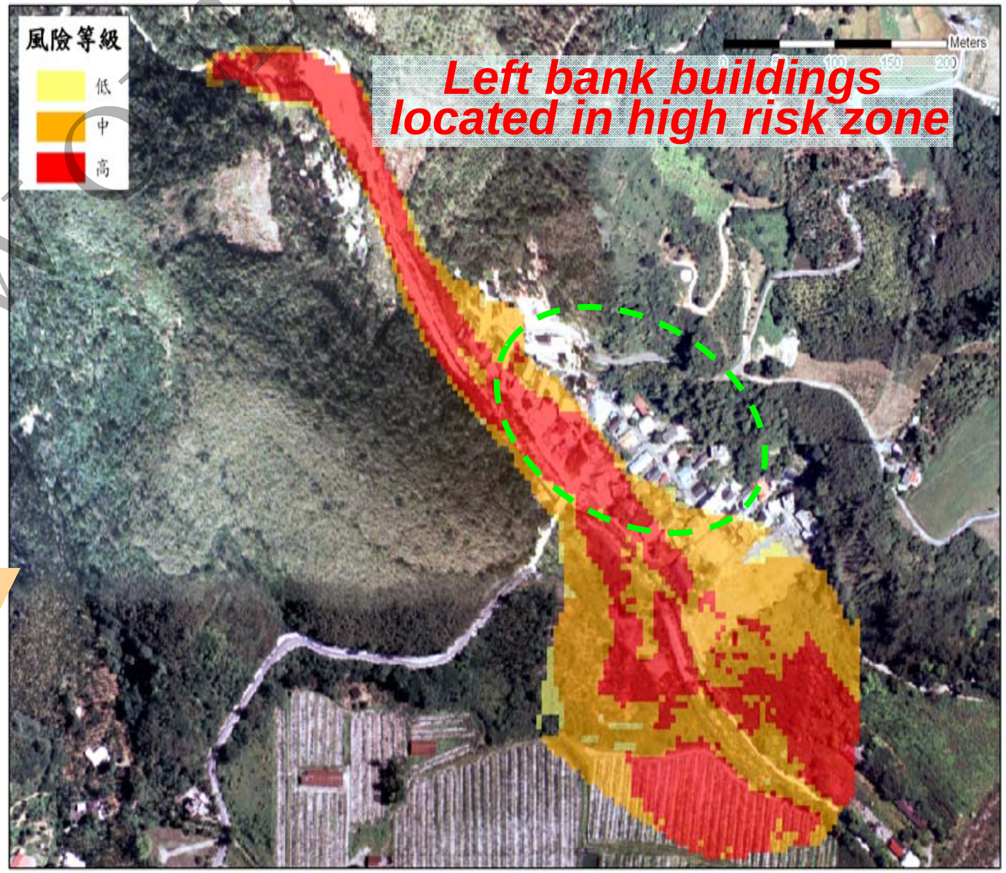
Max Depth Distribution (h)

FLO-2D Hazard Analysis module (hazard distribution)

GIS Layers (Aerial photo, road, buildings)

Risk map of Debris Flow

Warning Simulation of Debris Flow Disaster Condition

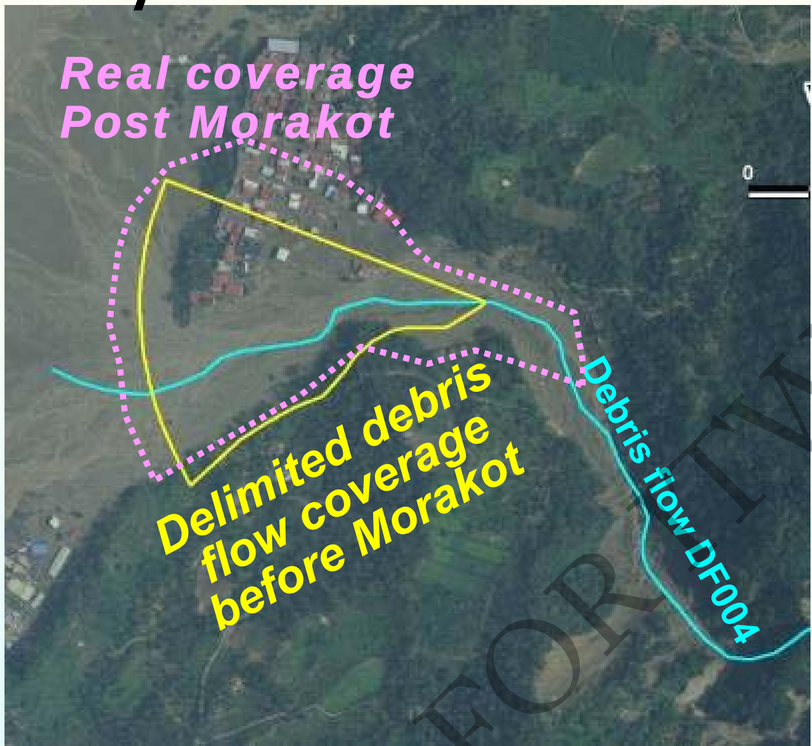


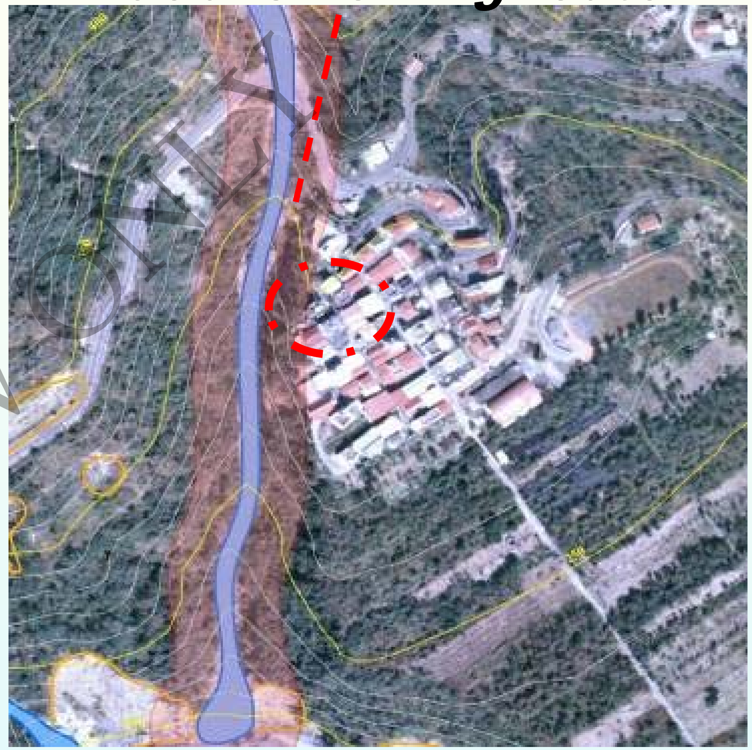
✓ Identification of the Affected Area in the Field

To check the coverage of deposition of debris flow

To evaluate the coverage of debris flowing route

高雄縣
那瑪夏鄉
民族村





高雄縣
茂林鄉
萬山村

✓Coverage Area of debris flow Disaster:

- After Typh. Morakot: By satellite image processing, 49 additional debris flows (44 caused by Typh. Morakot) are identified and there will be 1,552 debris flows in total in Taiwan.

✓**Potential hazard area:** determined by geology investigation and site reconnaissance.

Evacuation Routes and Drills for Debris Flow Disaster Mitigation

- 947 Evacuation routes planned
- 649 debris flow evacuation drills held
- 1385 Debris Flow Volunteer Specialists

Debris Flow Volunteer Specialist

Evacuation Route Map

Soil and Water Conservation Bureau (SWCB)

Debris Flow Emergency Operation Task Force of SWCB

Toll-free Hotline

0800-246-246

（土石流-土石流）

Emergency Response during Typhoon

- **Typhoon: Real-time weather condition**
- **Rainfall monitoring: Every 10 min**
- **Announce: Debris flow warning**

Debris flow information system

http://246.swcb.gov.tw

Localized Rainfall-based Debris-flow Warning Model

➢ Rainfall Triggering Index (RTI)

在地化雨量警戒模式

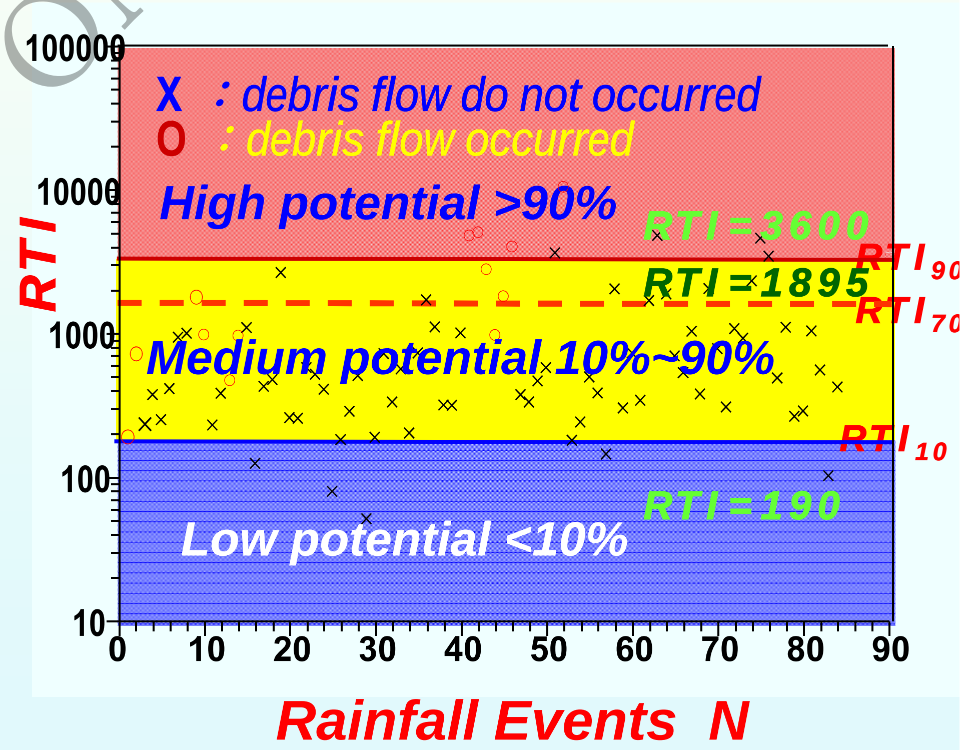
＝Rainfall intensity× Effective accumulated rainfall

$$RTI = I \times R_t$$

R_t：Effective accumulated rainfall
＝ Accumulated rainfall
＋ Preceding rainfall for 7 days

I：Rainfall intensity (mm/hr)

RTI_{70}： RTI at 70% of probability that debris flow occurred



- The critical accumulated rainfall for evacuation (Rc) is set for easier public understanding and local application

Does the public understand the warning model?

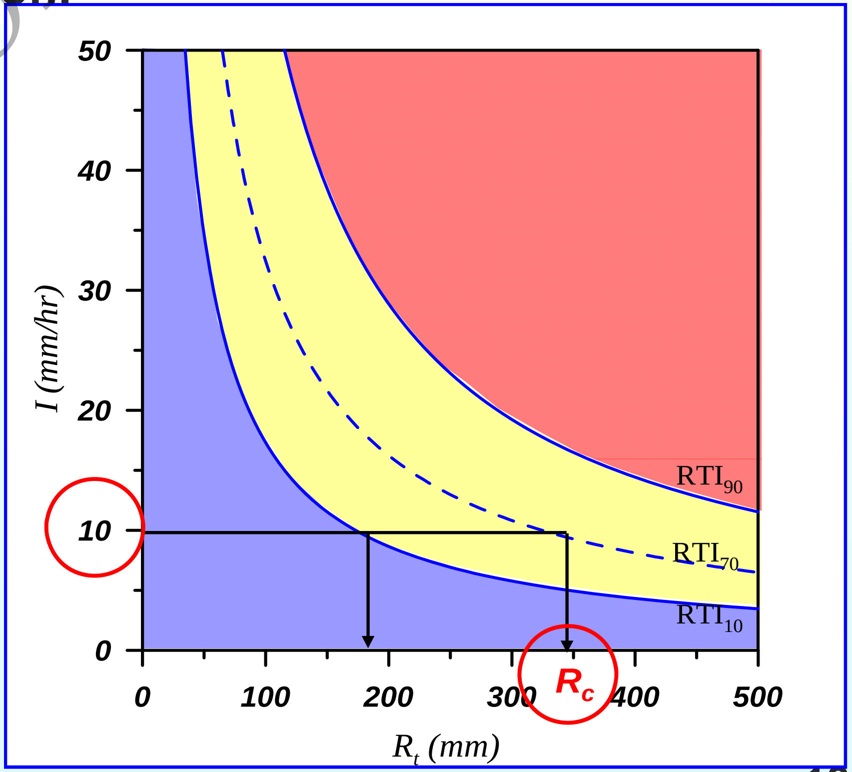
- **The answer is NO.**
- **People can understand the accumulated rainfall, but do not (do not want to) understand the rainfall intensity.**
- **Weather Bureau reports only the accumulated rainfall also.**
- **More simplified model for the public is needed.**

Simplified RTI model

The critical RTI-value involves two parameters (I and R) is too academic and not easy to understand for people living in mountainous areas.

The **critical accumulated rainfall** (R_c) is set for easier public understanding and application for evacuation.

Rc is estimated from the critical RTI-value with a consideration of rainfall intensity of 10 mm/hr, and rounded with 50mm as an interval of the critical accumulated rainfall. That is to say for different counties, *Rc* could be *200, 250, 300, 350, 400, 450, 500, 550, or 600 mm*.



Warning criteria Table

Village and (N)：the numbers of debris flow torrents in the village

Rainfall station 1

Rainfall station 2

101年土石流警戒基準值明細表

101.02修訂

縣市	鄉鎮	警戒區範圍		土石流警戒基準值 (mm)	參考雨量站	
		警戒區座落村里 (土石流潛勢溪流總數)	土石流潛勢溪流數(條)		代表站1	代表站2
	蘇澳鎮	朝陽里(4)	4	500	南澳	東澳
		南建里(1)、永春里(2)、長安里(1)、永樂里(7)、蘇北里(1)、聖湖里(4)	16		蘇澳	冬山
	三星鄉	集慶村(1)、拱照村(3)、天山村(1)	5	600	三星	寒溪

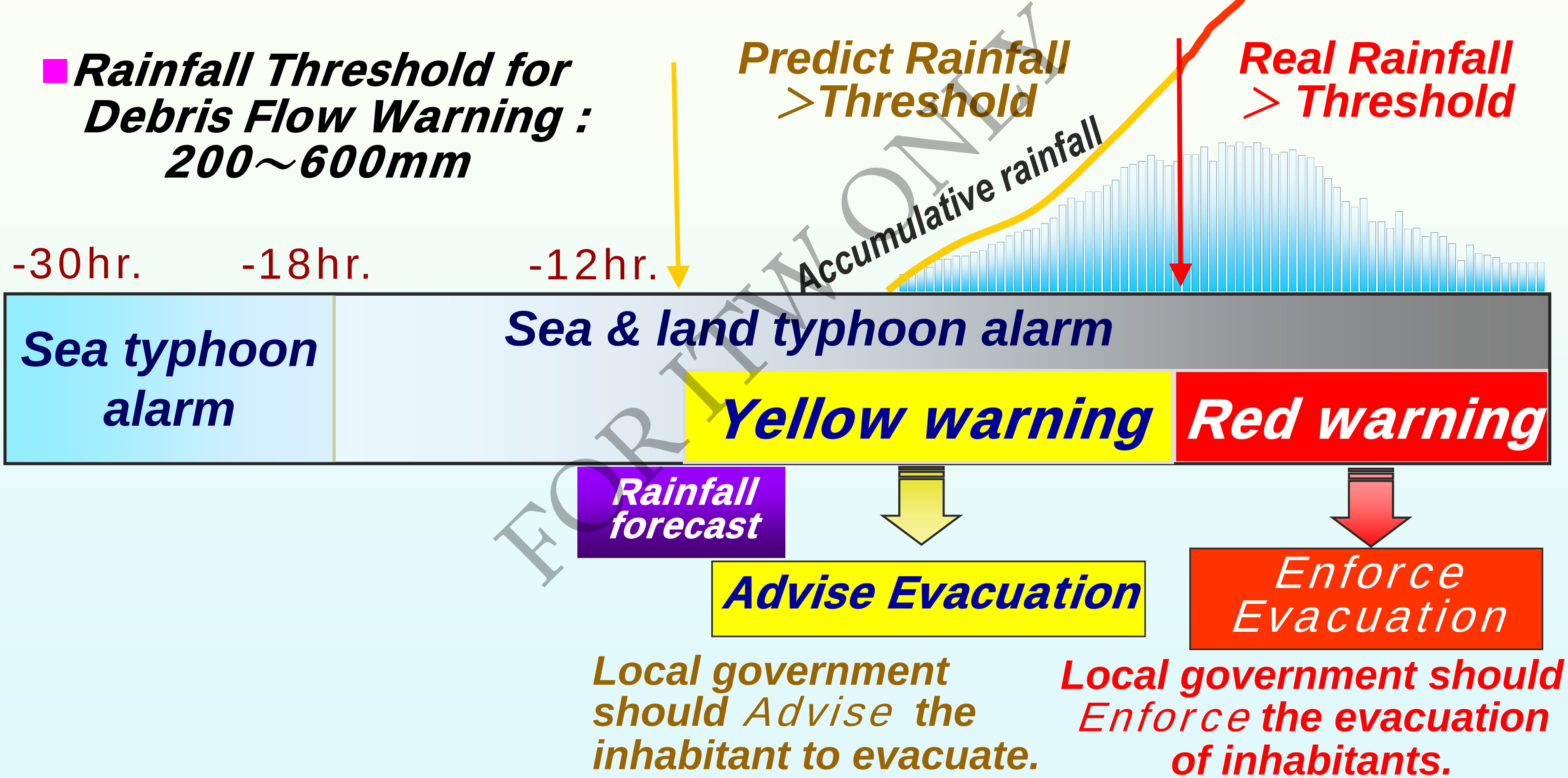
Township

Warning Criteria

Numbers of debris flow torrents in township

Announcement of Debris Flow Warning in Taiwan

- **Rainfall Threshold for Debris Flow Warning : 200～600mm**



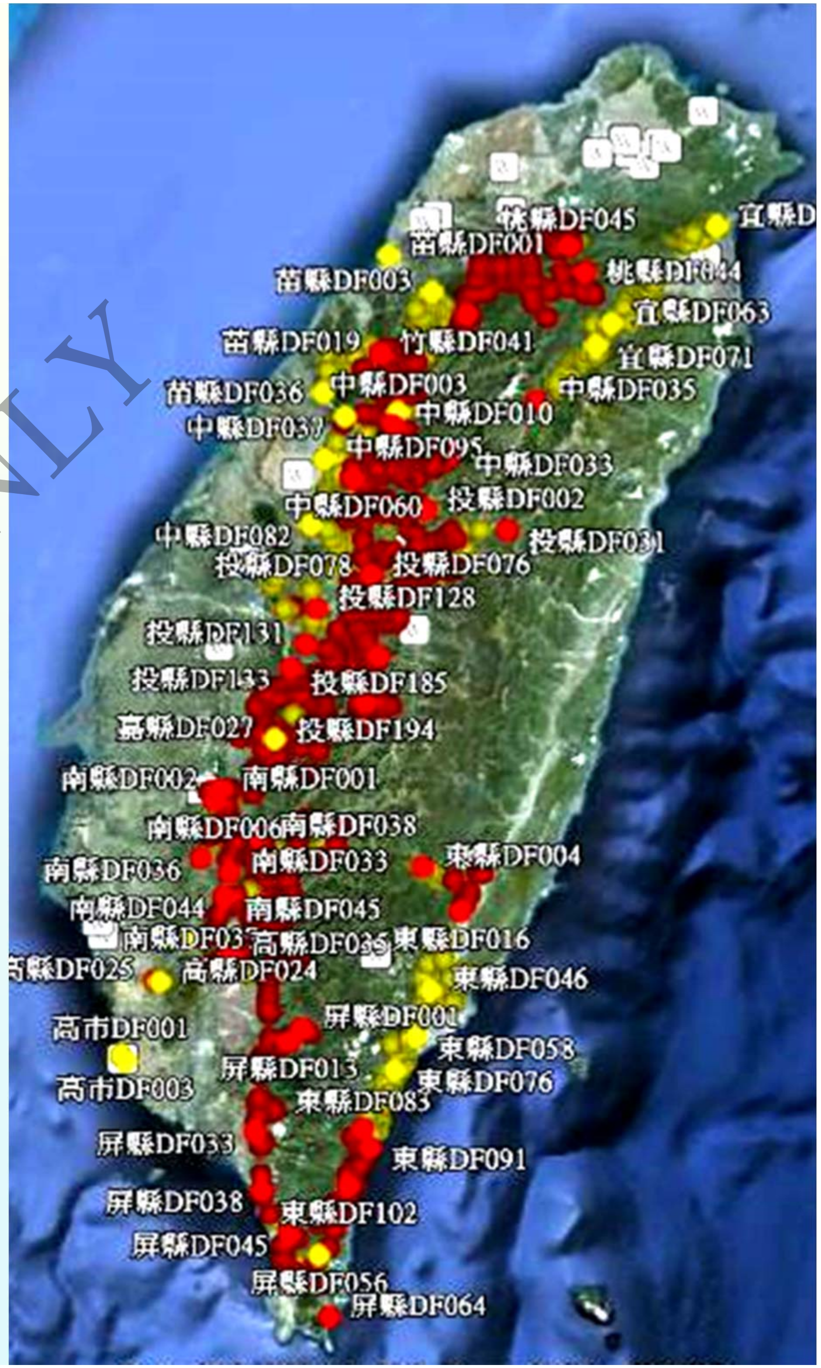
Soil and Water Conservation Bureau (SWCB)

Debris Flow Warning and Evacuation

- During the typhoon Morakot period, the SWCB had issued 21 debris flow warnings to the public and local governments based on the real-time weather information from CWB.

Debris flow warning	Warning ravines	County (City)	Town	Village
Red alarm	519	12	61	230
Yellow alarm	338	14	58	163

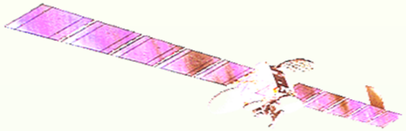
9,100 people were evacuated by local governments according to the warning. Among them, **1,046 people** escaped from the possible casualties.



3. On-site Debris Flow Observation

17 On-site (fixed) debris flow monitoring station

Monitoring Sensors



Satellite Transmission

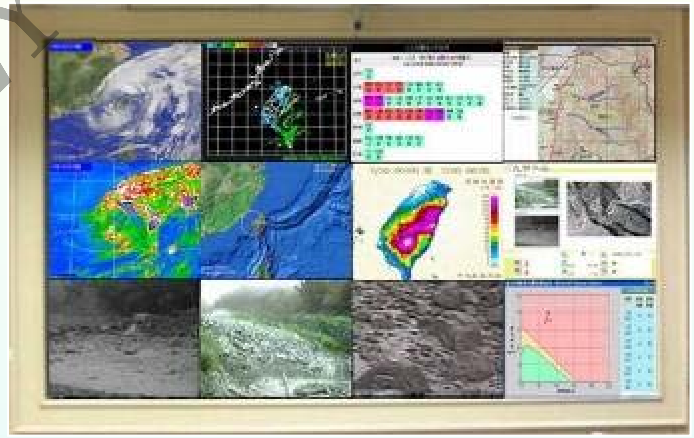
Instrumental cabin

Data-processing

Power-Supply

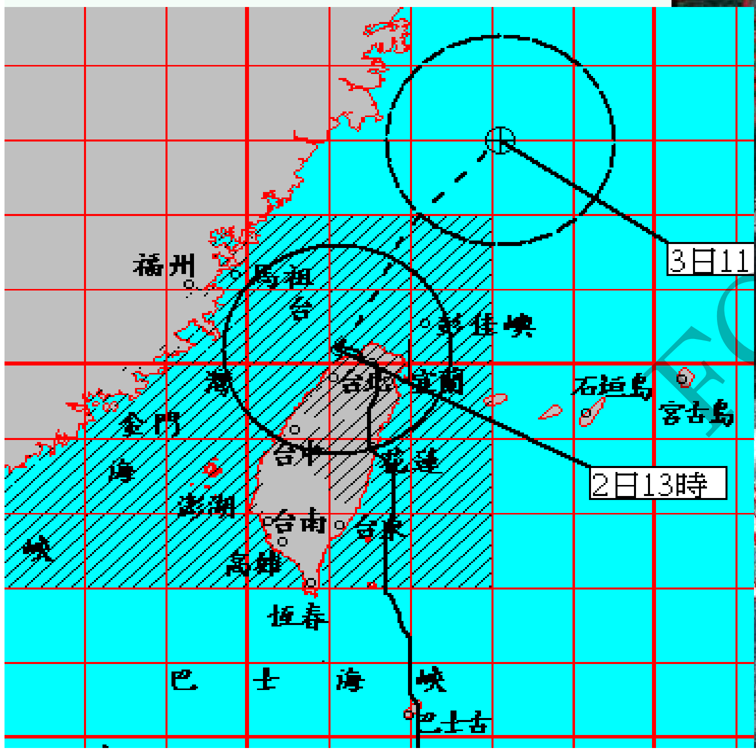
Information Display

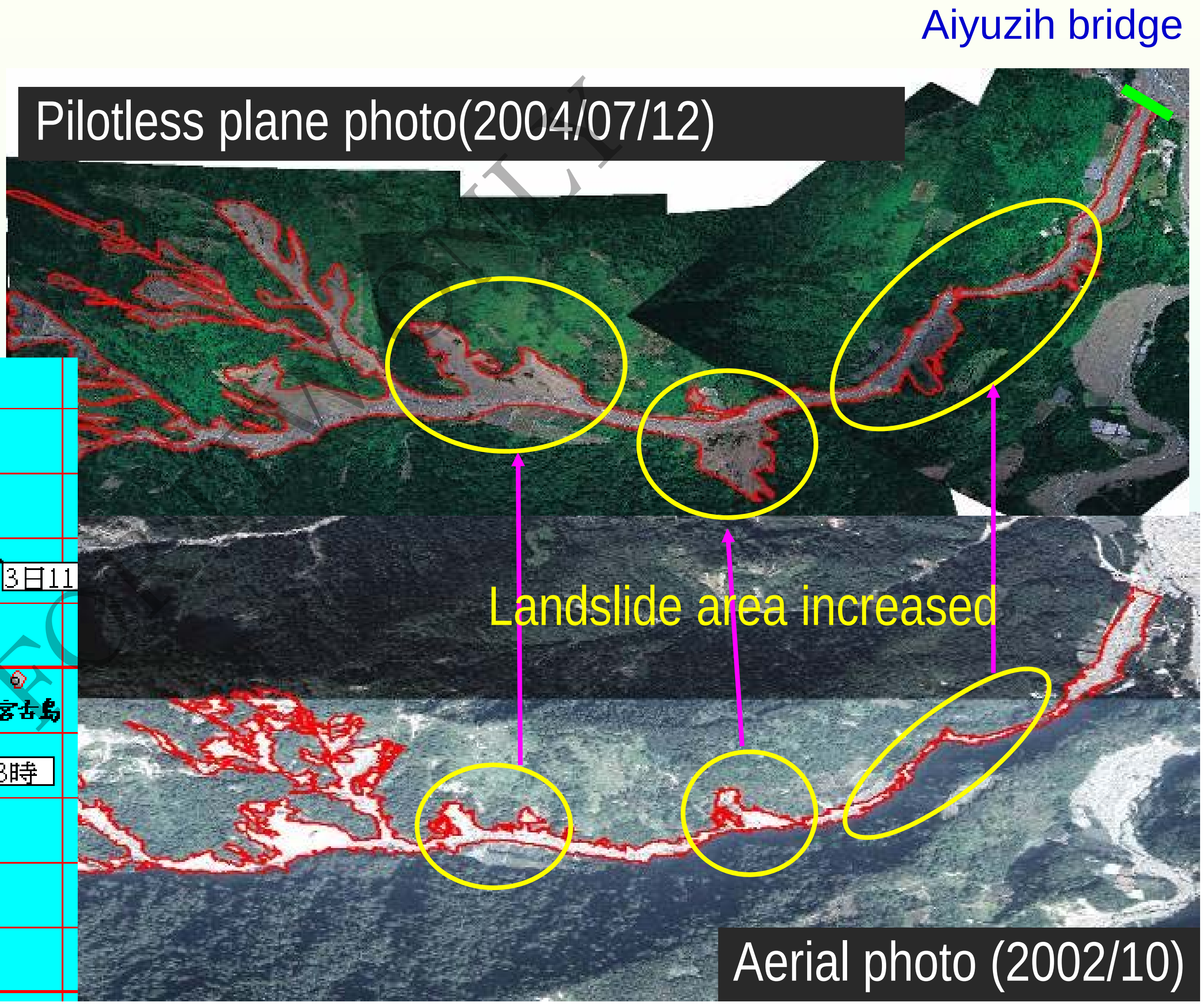
http://246.swcb.gov.tw



Field Observation Data

Debris flow disaster in Aiyuzih creek, Shenmu Village after typhoon Mindulle on July 2, 2004.





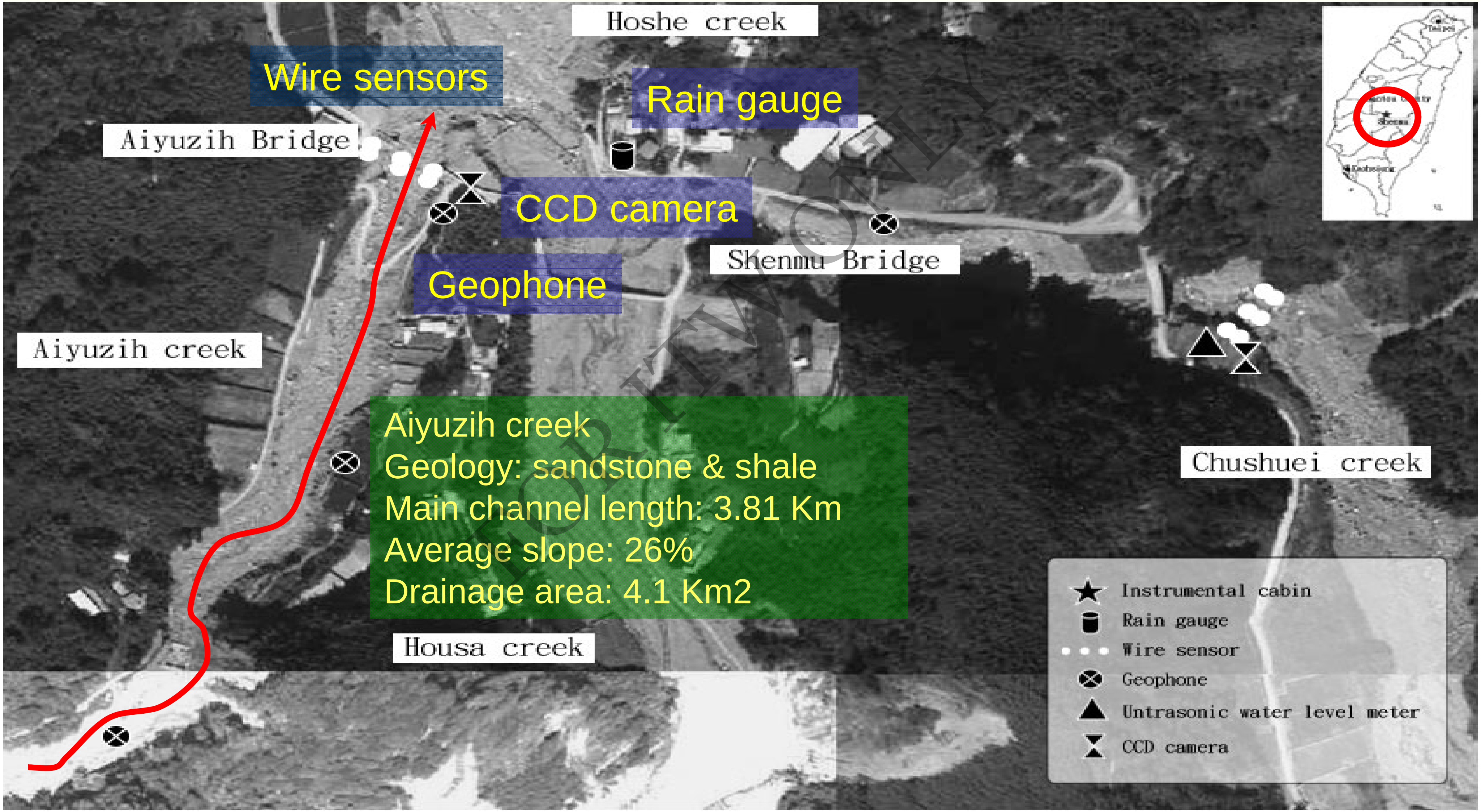
Images from Unmanned Aerial Vehicle (UAV)
(Aiyuzih creek)

1996

2009

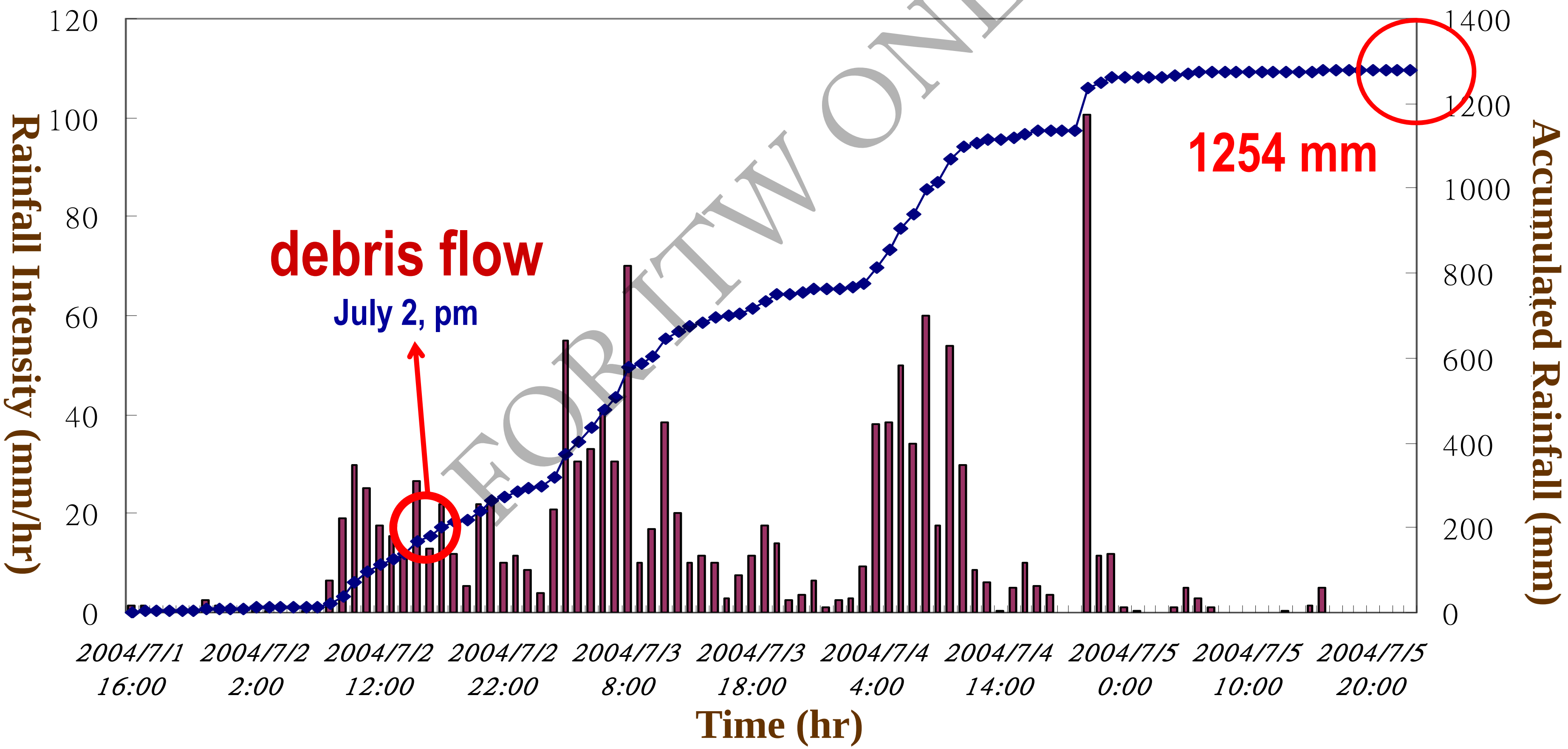
Allocation of monitoring instruments

Shenmu debris flow monitoring station

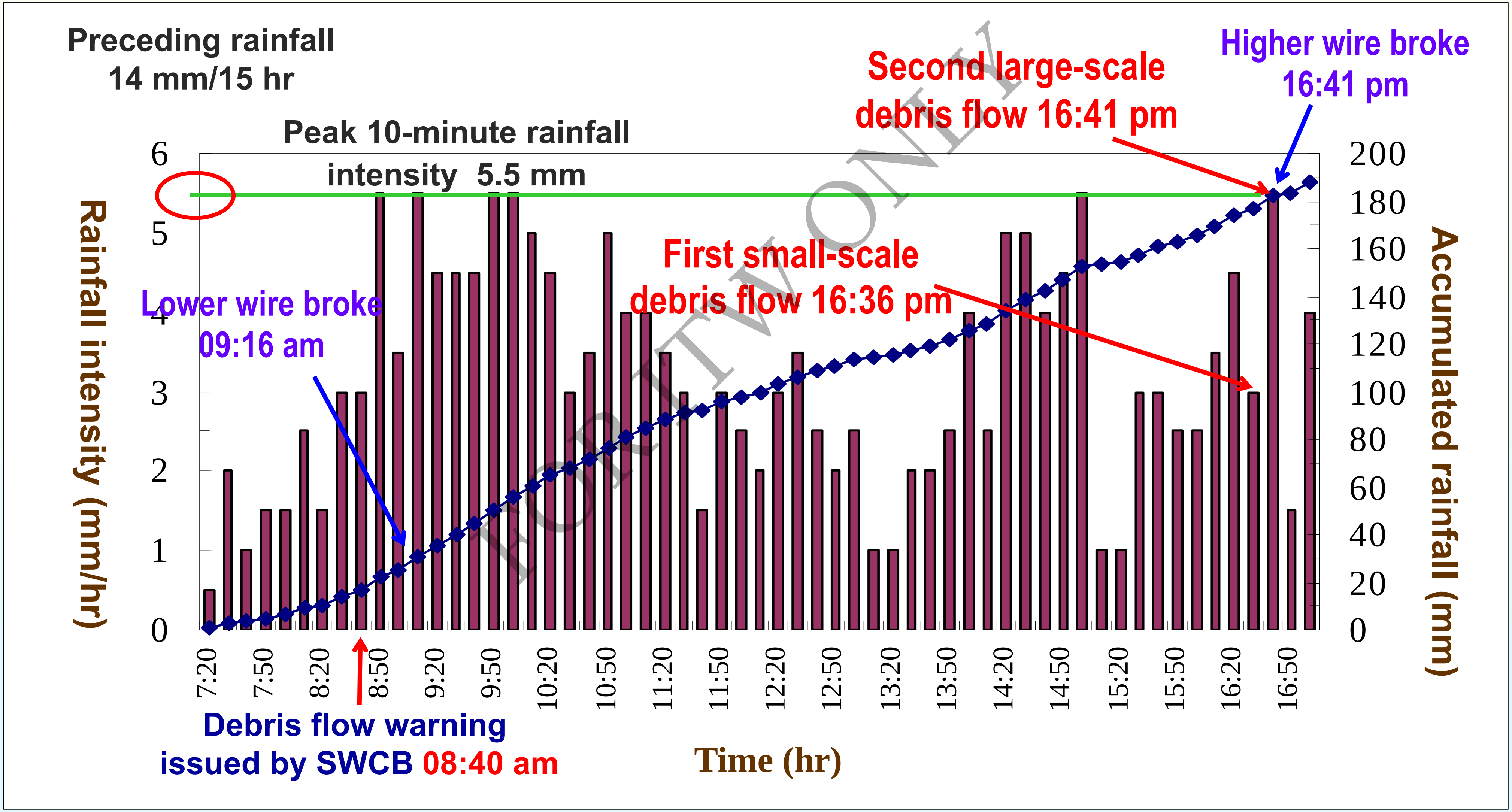


Field observation data

Rainfall data in Shenmu monitoring station from July 2 to 5, 2004



Rainfall data in Shenmu station (Aiyuzih creek) from 07:20 to 17:00 on July 2, 2004

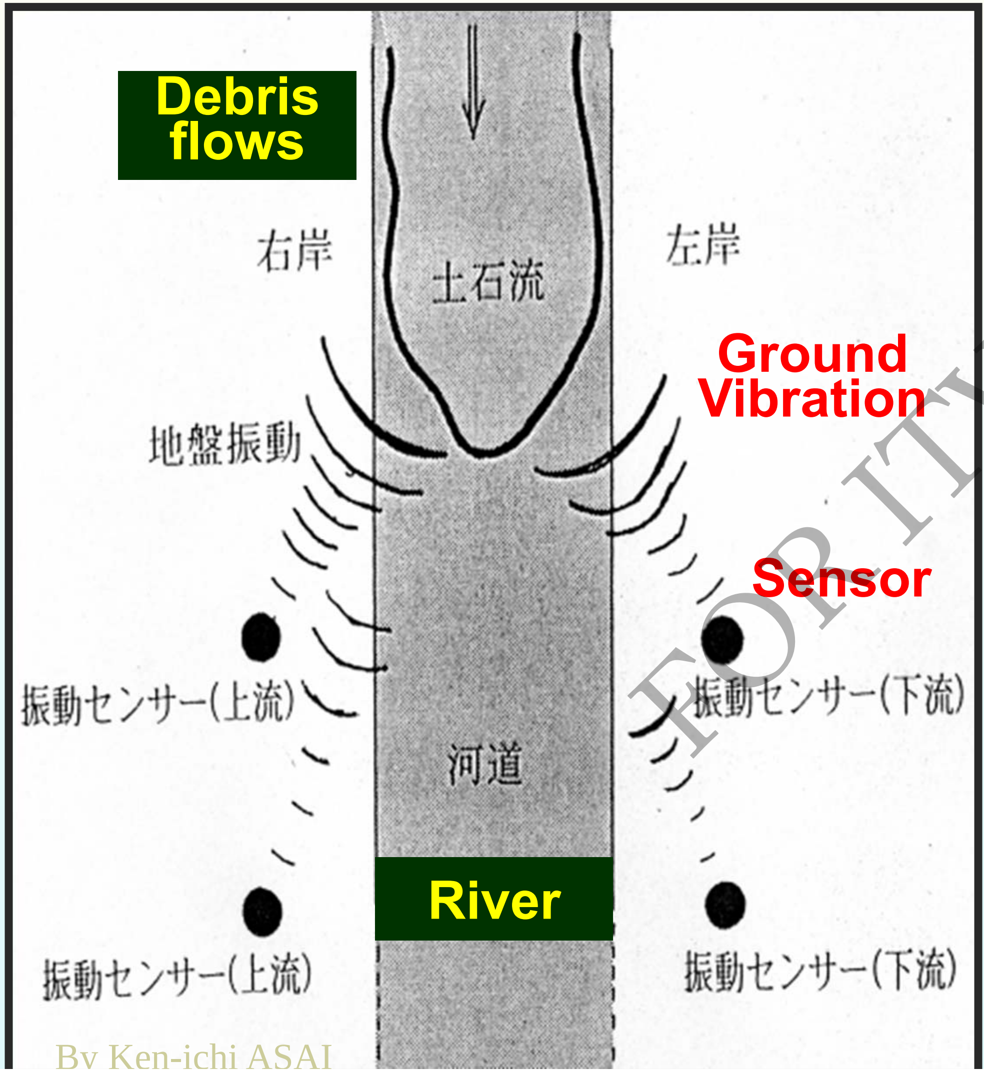


Characteristics of debris flows form image data

1. A very low discharge just before the surge
2. Accumulation of large boulders at debris flow front
3. Wavy surface of debris flows
4. A rapid decrease of the flow depth behind the front

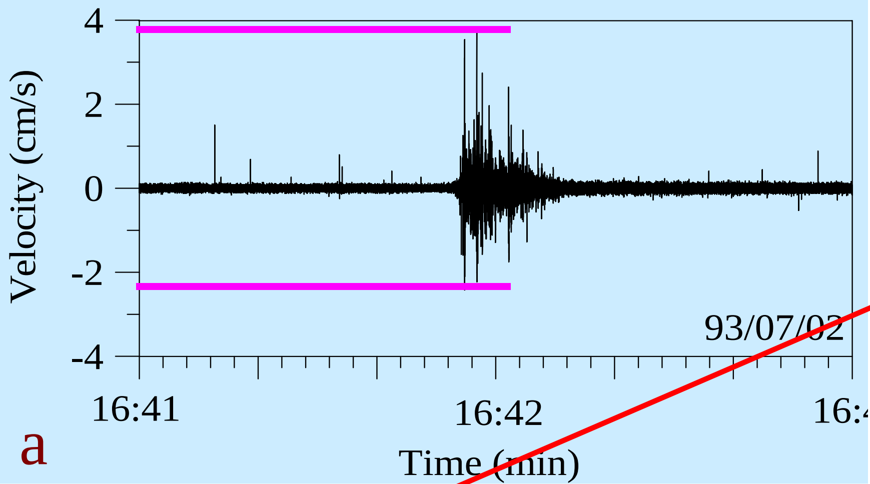
- the average velocity of front surge 13 m/sec
- the flow depth of the front surge between 5.5 to 6 m
- maximum particle size about 4 to 5 m
- the average flow depth of 2 m
- flow duration of about 5 minutes

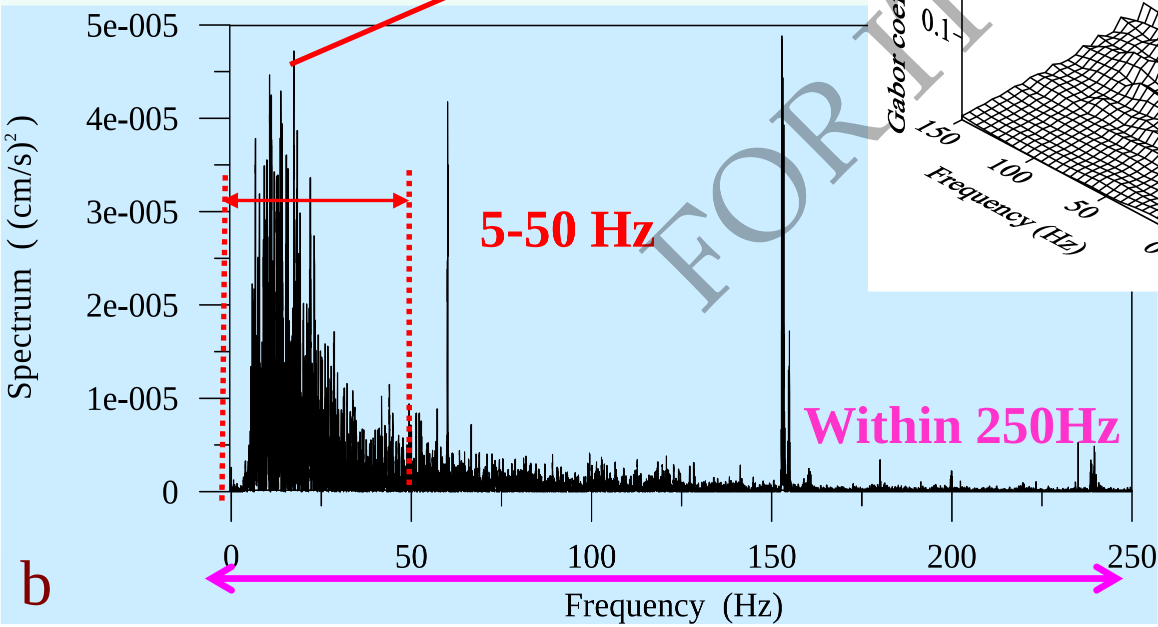
Ground vibration generated by debris flow

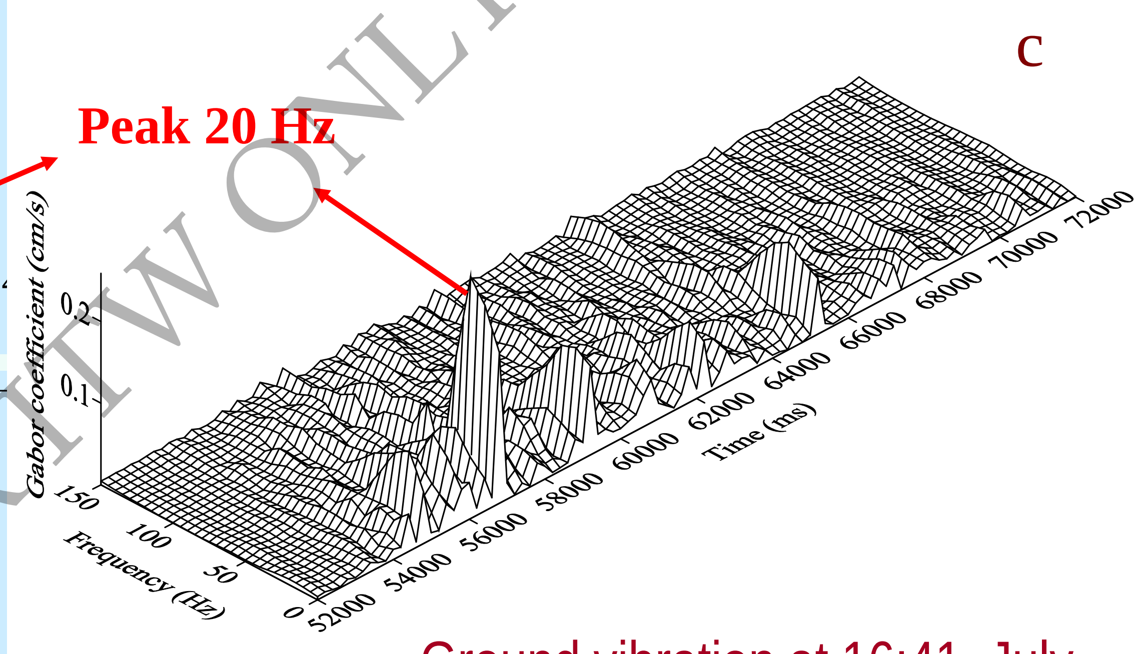


- During the debris flows, one can hear a roaring sound and experience ground vibration (or so called underground sound).
- → New way for early warning of debris flows occurrence.

Second large-scale debris flow detected by geophone







Ground vibration at 16:41, July 2, 2004 (X axis)
(a) time domain signals
(b) spectrum of FFT
(c) spectrum of GT

Deployment of serial geophones

→ In order to estimate the velocity of debris flow front surge, the geophones are deployed along the riverbank serially.

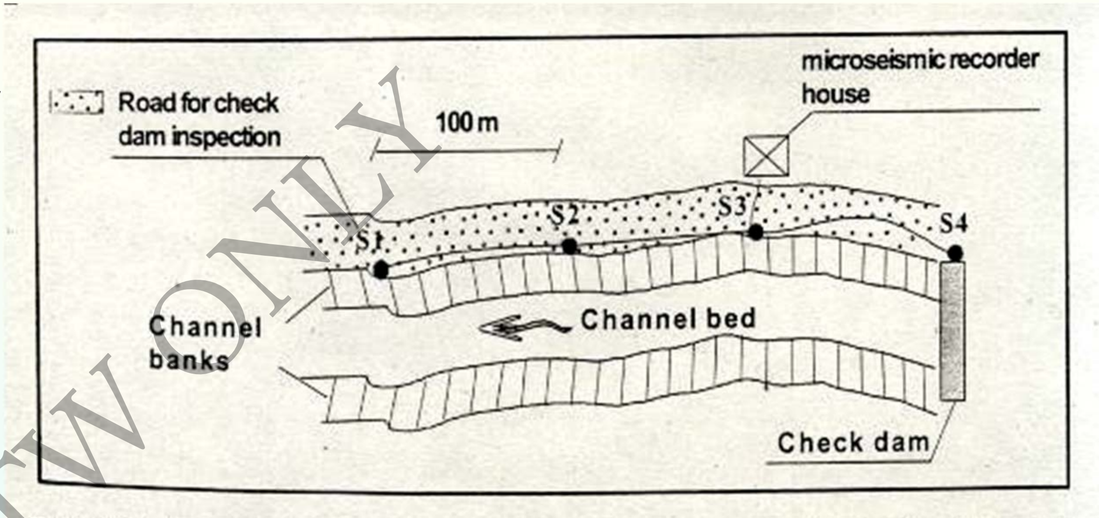
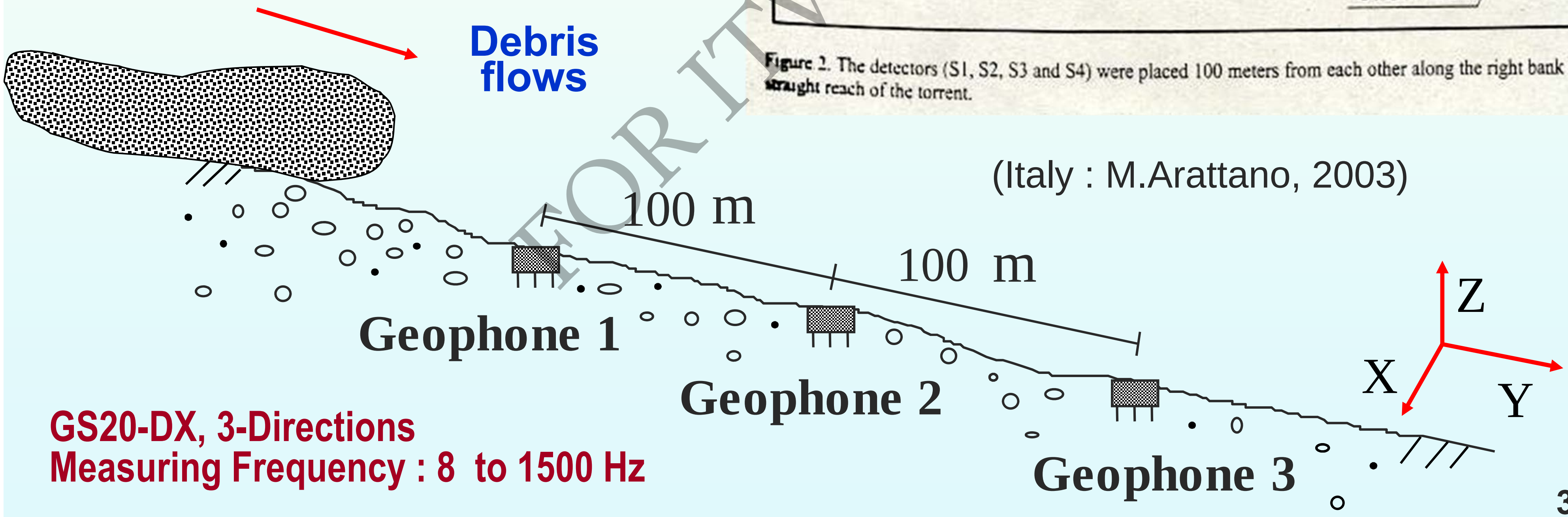


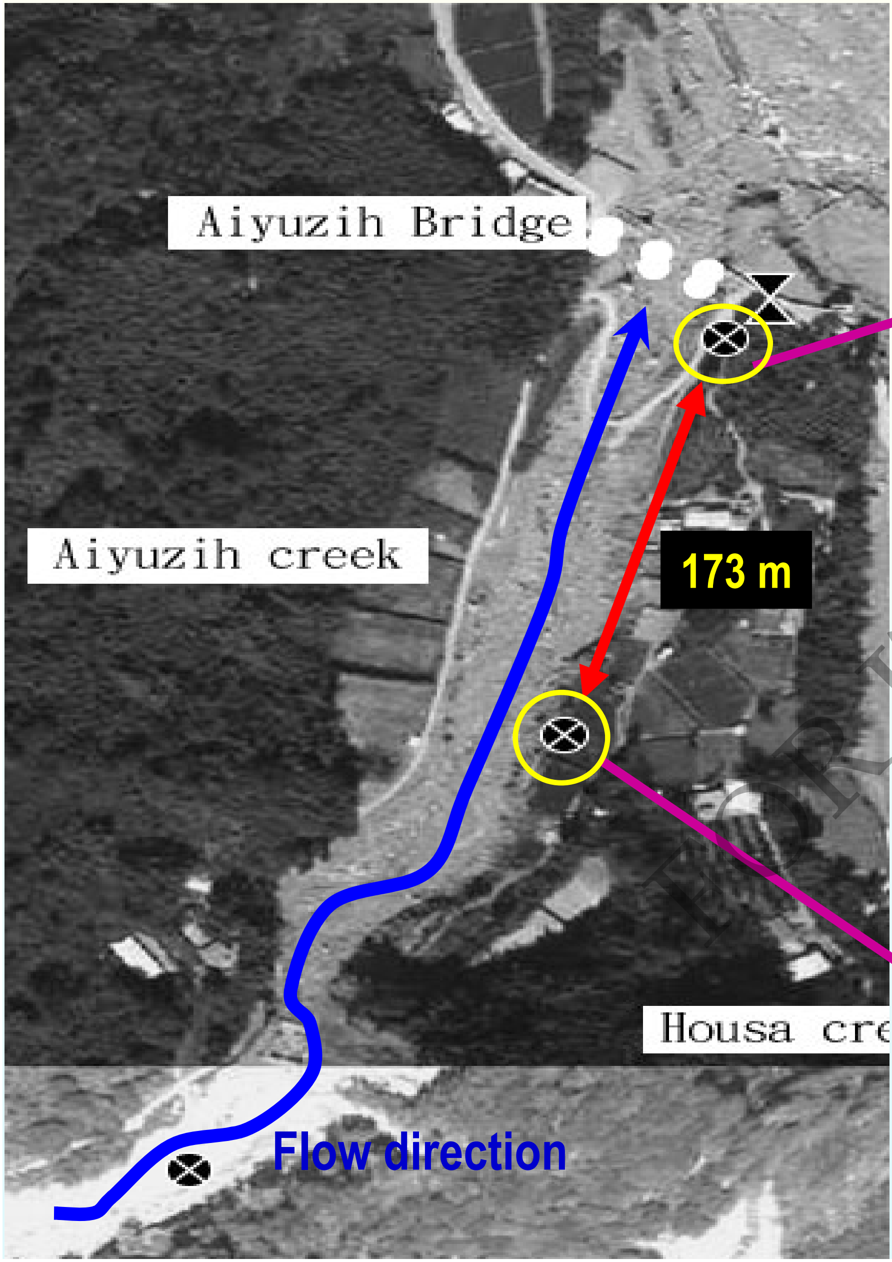
Figure 2. The detectors (S1, S2, S3 and S4) were placed 100 meters from each other along the right bank of a straight reach of the torrent.

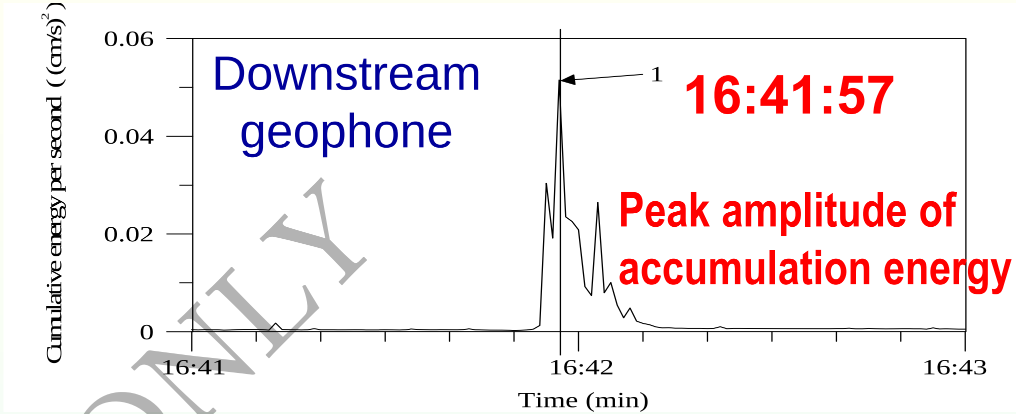
(Italy : M.Arattano, 2003)



GS20-DX, 3-Directions
Measuring Frequency : 8 to 1500 Hz

Average velocity of debris flow front surge

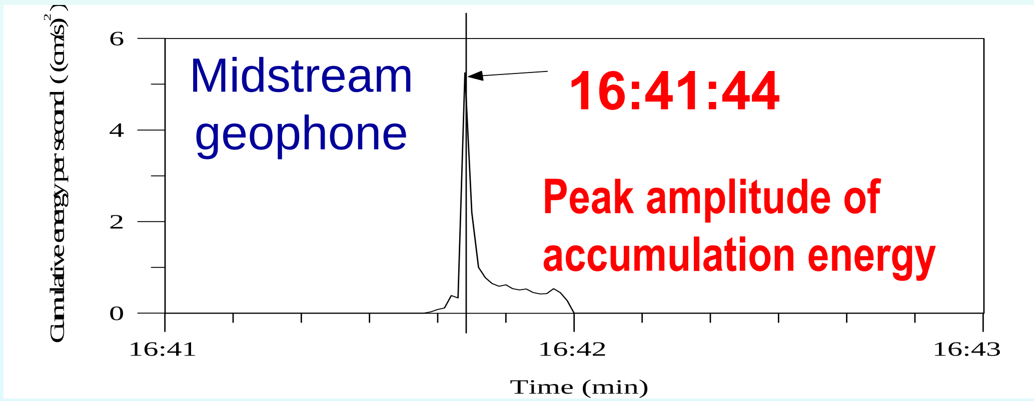




$$E = \int_{t_i}^{t_{i+1}} (V_x^2 + V_y^2 + V_z^2)\,dt$$

E:Accumulation energy
V:Velocity amplitude
dt:0.25 sec

$$V = \frac{173\ \text{m}}{13\ \text{sec}} = 13.3\ \text{m/s}$$

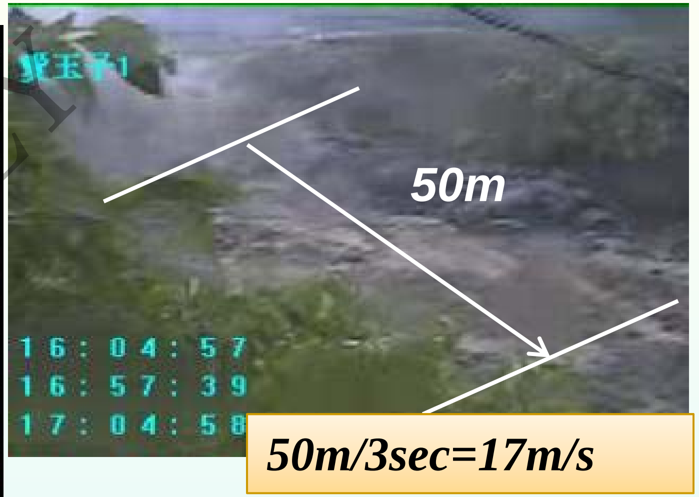


Monitoring Results – Shenmu Station 2009

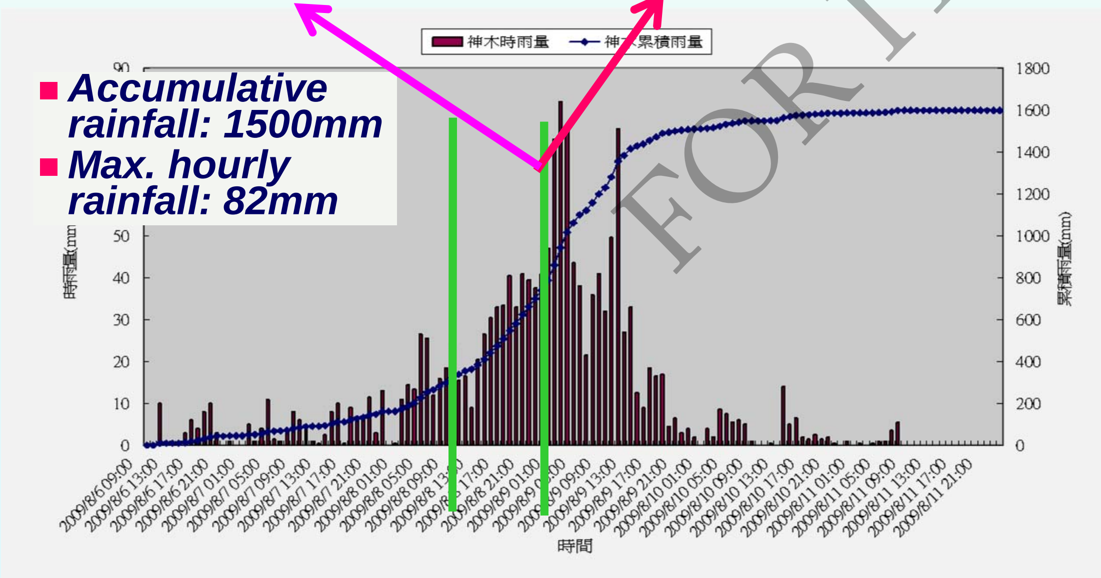
CCD image (front view) of Aiyuzi downstream

CCD image (sideview) of Aiyuzi upper stream

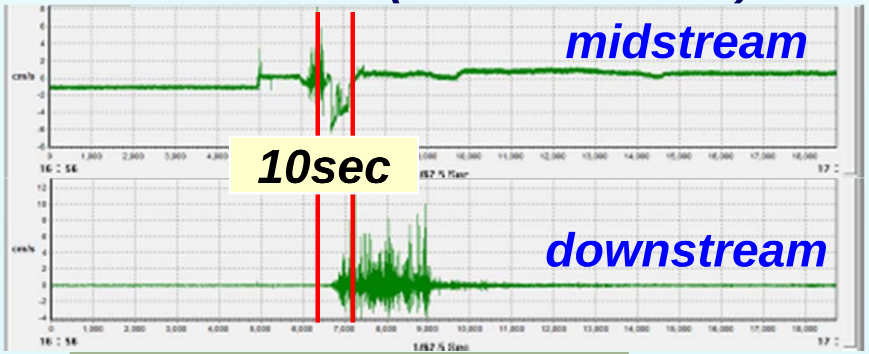
Velocity



- Accumulative rainfall: 1500mm
- Max. hourly rainfall: 82mm

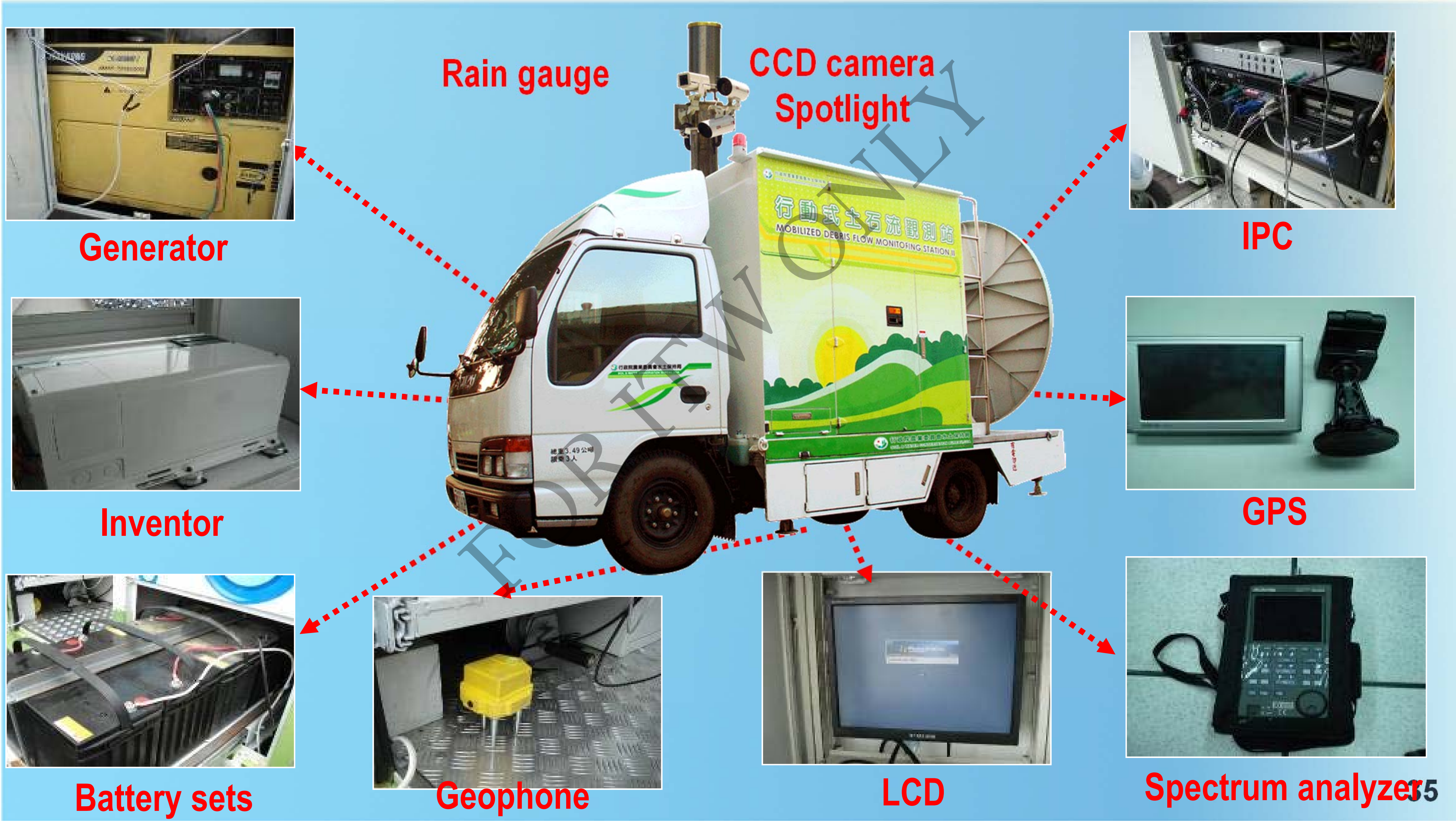


- Geophone signal after wavelet transform (8/8 16:56~17:00)



173m / 10sec =17m/s

3 Mobile debris flow monitoring station (since 2004)



Real time monitoring of dammed lake

(4 million m^3 of water storage) **July 23, 2006**

Lung-Chuen stream, Taitung County (eastern Taiwan)

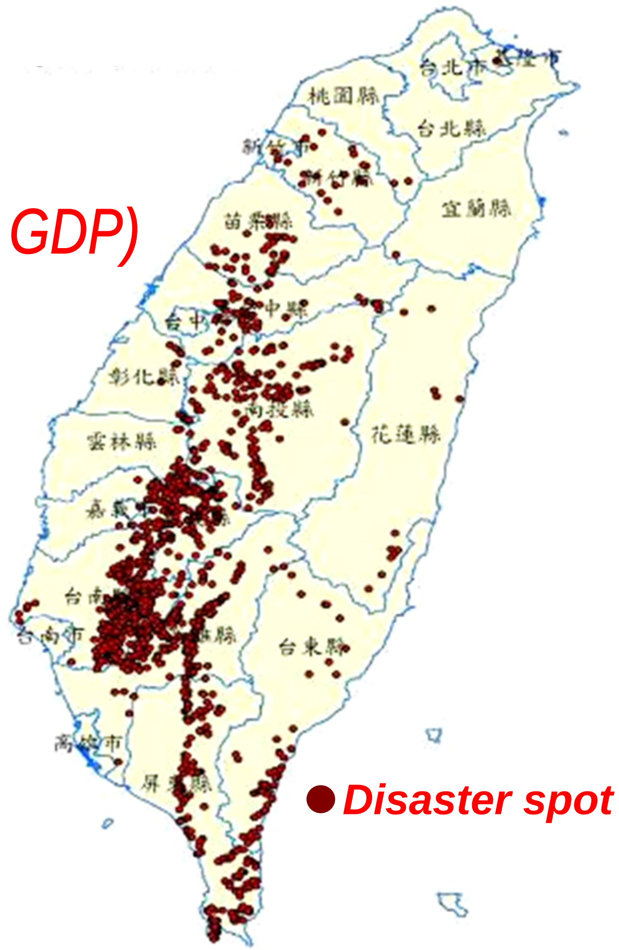
14 Grid debris flow monitoring station *(since 2010)*

4. Challenges and Future Perspective

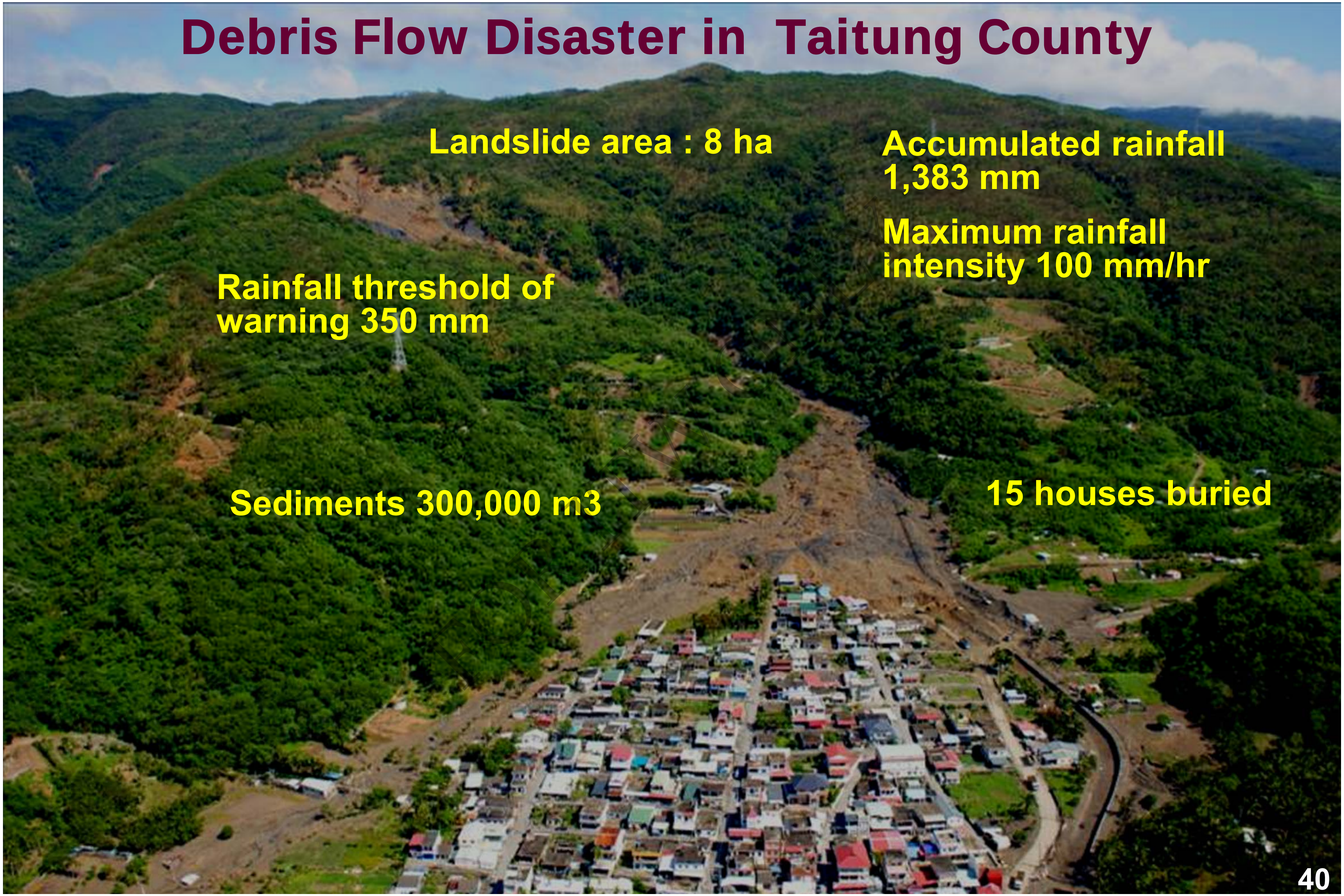
Soil and Water Conservation Bureau (SWCB)

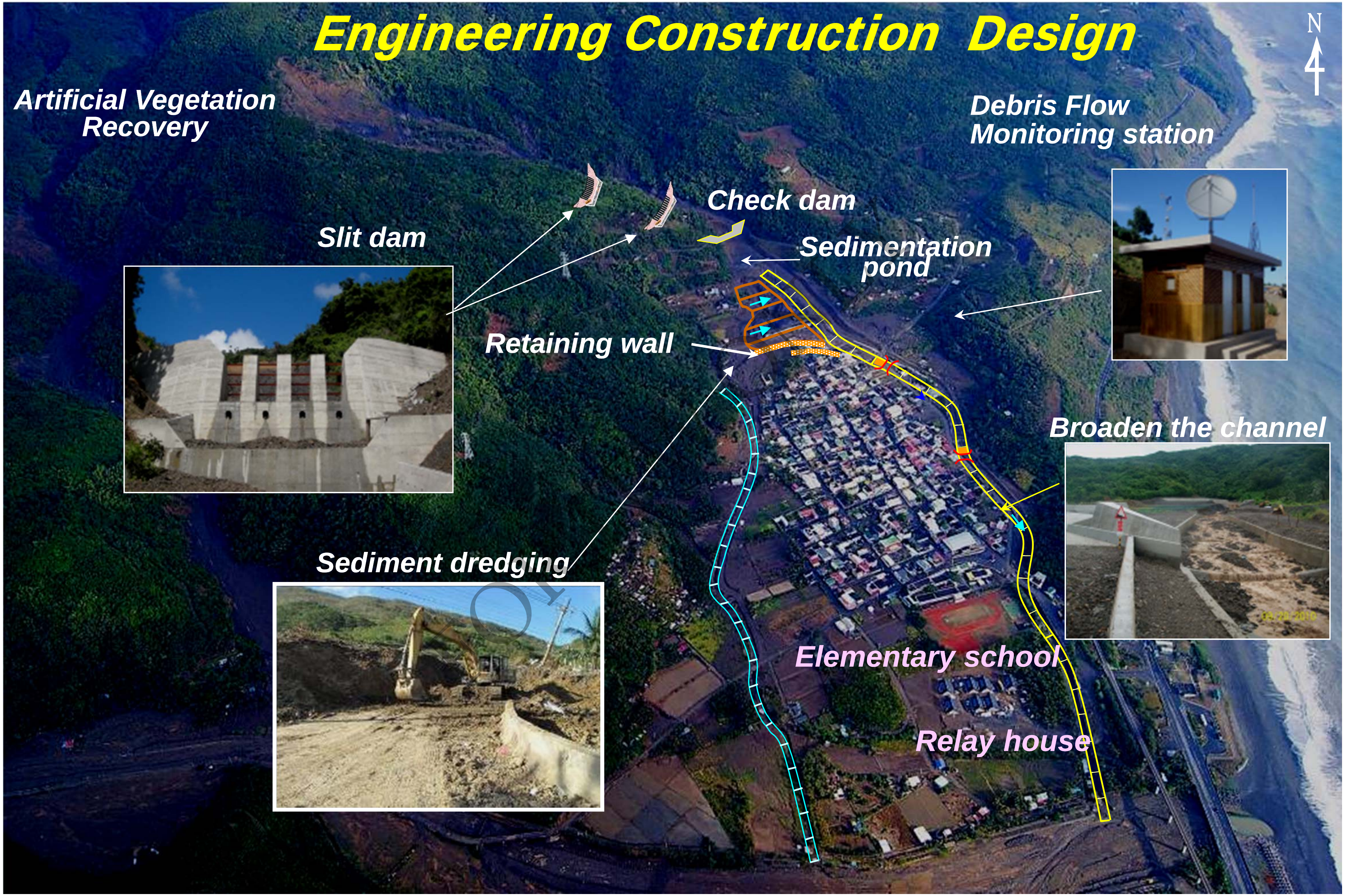
✓Damage of Calamity Caused by Typhoon Morakot (Aug 6-10, 2009)

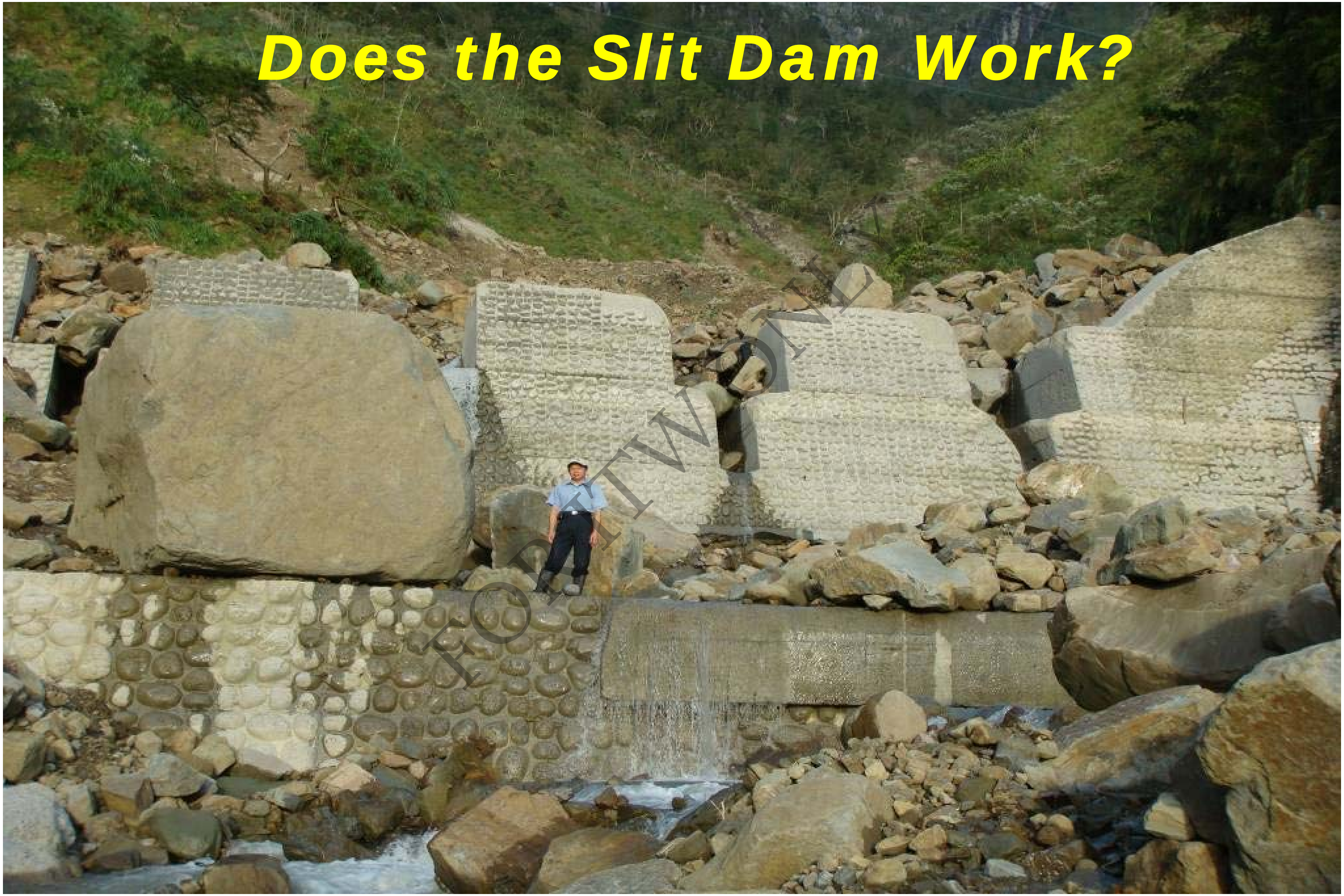
- *Max. accumulated rainfall (Aug 6-10, 2009): 3059.5mm.*
- *Coverage area of total rainfall ≧2000mm: 320,000km².*
- *Total new landslides: 39,492 ha.*
- *Evacuate and withdraw: 24,950 people.*
- *Casualty and missing: 757 people.*
- *Total damage: 90.45 billion NTD(3 billion USD, 0.67% GDP)*



Debris Flow Disaster in Taitung County




Engineering Construction Design
Artificial Vegetation Recovery
Debris Flow Monitoring station
Check dam
Slit dam
Sedimentation pond
Retaining wall
Broaden the channel
Sediment dredging
Elementary school
Relay house
N

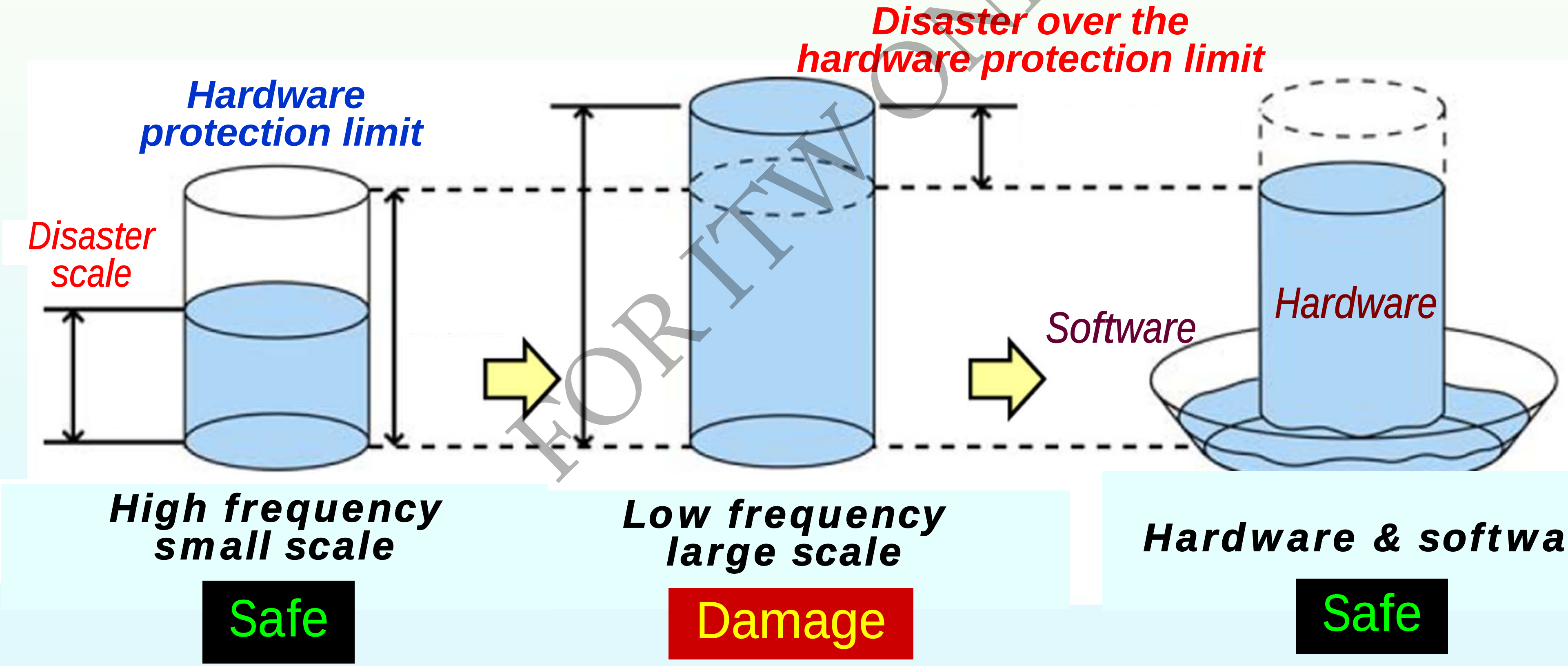

Does the Slit Dam Work?

Recent Typhoon Washi in Philippines, Dec 2011

- ***Accumulated rainfall : 181 mm within 24 hr***
- ***Casualty : 652, Missing : over 900 people***
- ***It were not frequent to have typhoon disasters in southern Philippines***
- ***National disaster response department issued the warning to the people in southern Philippines 3 days before the attack, but the local residents did not pay much attention to it.***

Integration of Software and Hardware

- ***Under climate change impact, strategy of disaster precaution should be considered from hardware to software.***
- ***Non-engineering measures should combine with mitigation works.***



(摘自日本地方再生戰略，2008)

Future Perspective for Natural Disaster Management
－T.H.I.N.K－

- *Technology ：Research, development and practice.*
- *Human management ：Improve people's awareness of precaution against disaster.*
- *Investigation ：Investigate the potential locations to cope with disasters.*
- *Notice ：Accurately control possible occurring time and give a declaration.*
- *Knowledge ：Information and database as well as expert decision- making system.*


Thank You for
Your Attention
Soil and Water Conservation Bureau
Always Working with You