Soil & Water Conservation Bureau

2010 International Training Workshop on Natural Disaster Reduction

Multi-Strategies of Debris Flow Disaster Management in Taiwan

Hsiao-Yuan(Samuel) Yin

Section Chief, Ph.D.
Soil and Water Conservation Bureau (SWCB)
Council of Agriculture, Taiwan

Soil & Water Conservation Bureau

Outline

- Introduction
- Debris Flow Disaster Mitigation and Management
- Debris Flow Monitoring System
- Debris Flow Disaster Recovery

  Hua-shan Village -Case Study-

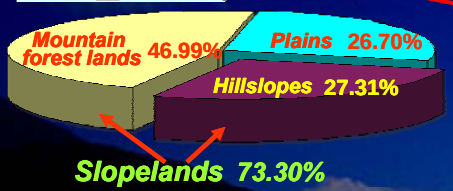
Soil & Water Conservation Bureau

Introduction

Soil & Water Conservation Bureau

Introduction

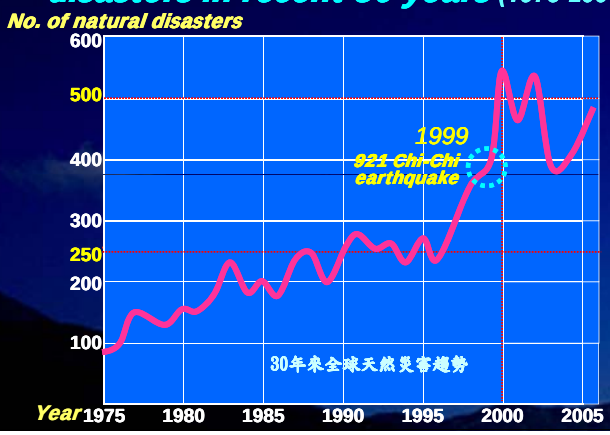
Taiwan is located at the convergent boundary of the Eurasian Plate and the Philippine Sea Plate.



Land Resources Distribution

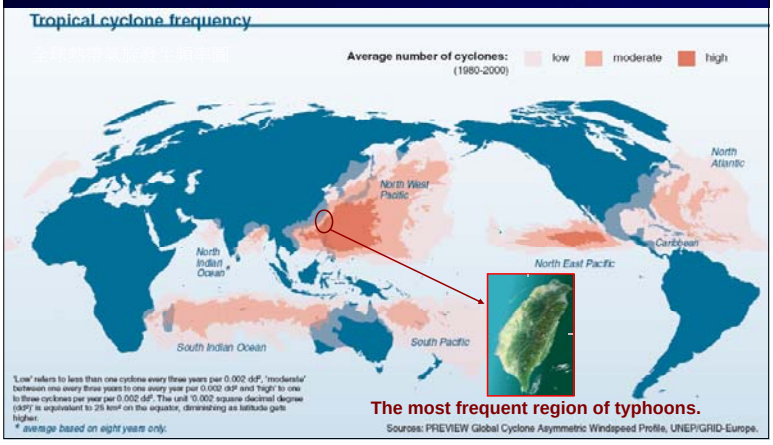
Soil & Water Conservation Bureau

Global increasing trend of natural disasters in recent 30 years (1975-2006)

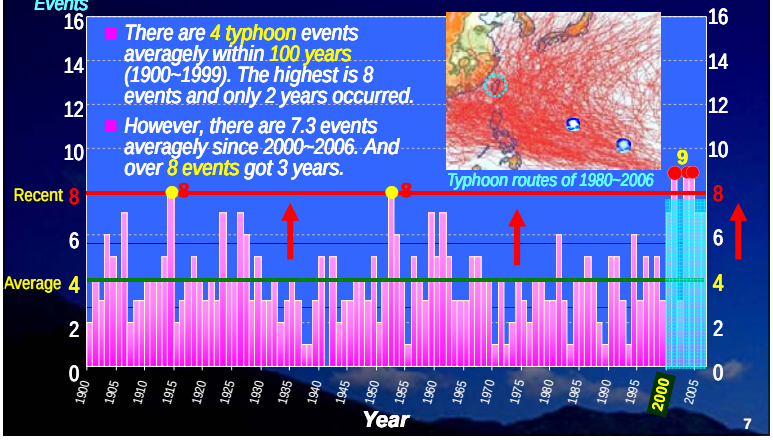


Soil & Water Conservation Bureau

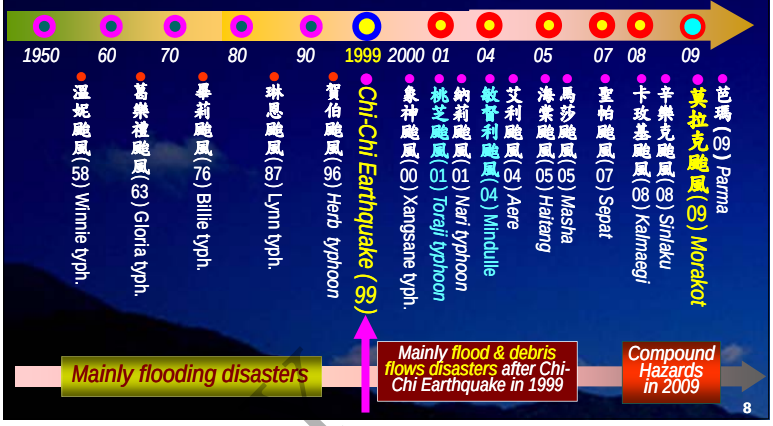
Taiwan is subject to tropical cyclone (typhoon)



Increasing Trend of Typhoon Events (1897~2006)



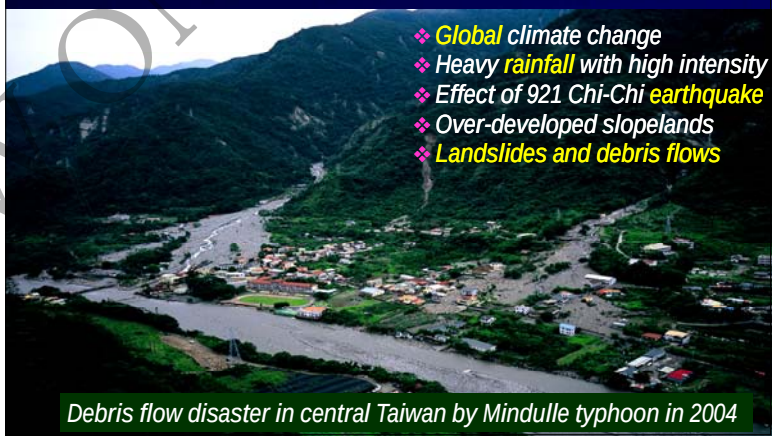
Historic Typhoon Disasters in Taiwan



✓Calamity of Typhoon Morakot,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: NT$90.45 billion dollars.

Factors governing slopeland disasters



Debris flow disasters in Taiwan

Council of Agriculture

Soil & Water Conservation Bureau Organization Chart

Total personnel : 537
Annual Budget : 8.6 billion NTD

- Director-General
- Deputy Director-General
- Chief Secretary
  - Planning Division — 3 Sections
  - Watershed Conservation Division — 4 Sections
  - Rural Reconstruction Division — 4 Sections
  - Monitoring & Management Division — 4 Sections
  - Debris Flow Disaster Mitigation Center — New
  - Secretariat
  - Personnel Office
  - Accounting Office
  - Government Ethics Office
  - 6 Regional Branches — 4 Sections

Debris Flow Disaster Mitigation and Management

Debris Flow Disaster Management

Hazard Preparedness

Investigation & Evaluation of Vulnerability of Potential Debris Flow

✓ **Village-based Investigation**

- Village-based investigation to delimit the coverage of all types of hazard.
- The hazard of village often take place on different topographical interface.

✓ **Vulnerability Factors**

- Types of Hazard:
  - Valley-wise: Debris Flow
  - Slope-wise: Landslide
  - River Terrace: Erosion

✓ **Influential Area Estimate**

Debris Flow Torrents & Landslides

- Potential Debris Flow Torrents
  1,552 Torrents
- Landslide Areas
  46,950 ha

Potential Debris Flow Torrents

Historic Landslides Distribution

✓ Vulnerability Factor of Debris Flow

To check the coverage of deposition of debris flow

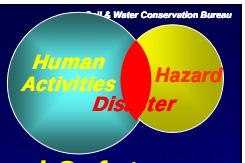
To evaluate the coverage of debris flowing route

✓ **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.

Investigation of Debris Flow Torrents



Risk Degree = Probability X Assured Safety

Low: Risk≦40, Mid: 40<Risk<60, High: Risk≧60

Factors of Probability

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

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

Assured Safety

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

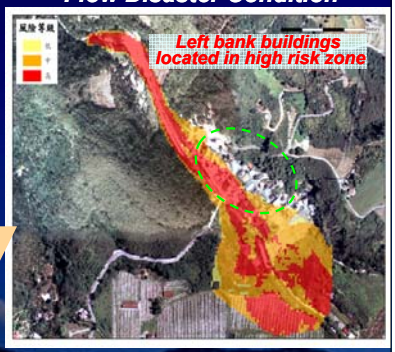
Soil & Water Conservation Bureau

Risk Mapping

Debris Flow Risk Mapping

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



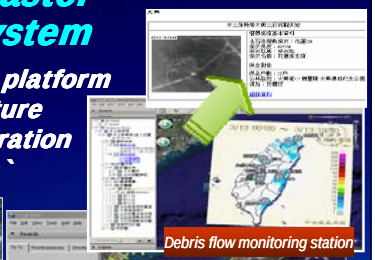
19

Soil & Water Conservation Bureau

Visualization of Disaster Management System

Google Earth

- Google Earth served as the platform
- Open map service architecture
- Disaster-related data integration
- Visualized Display Platform `



20

Soil & Water Conservation Bureau

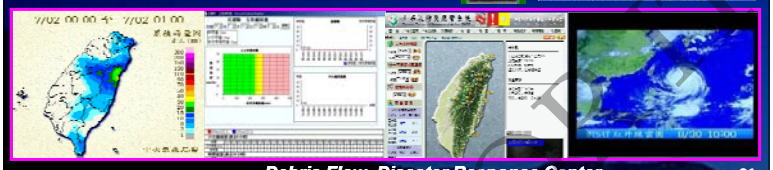
Contingency Response during Disasters

- Rainfall monitoring: Every 10 min.
- Typhoon: Cloud satellite image
- Announce: Debris Flow Warning
- Inform emergency messengers
- Heavy equipments standby at dangerous areas

Toll free

0800-246-246
（土石流-土石流）

Debris flow information website
http://246.swcb.gov.tw



Debris Flow Disaster Response Center

21

Soil & Water Conservation Bureau

Localized Rainfall-based Debris-flow Warning Model

Rainfall Triggering Index (RTI)

在地化雨量警戒模式

= Rainfall intensity x Effective accumulated rainfall

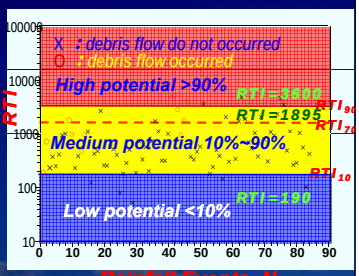
$$RTI = I \times R_t$$

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

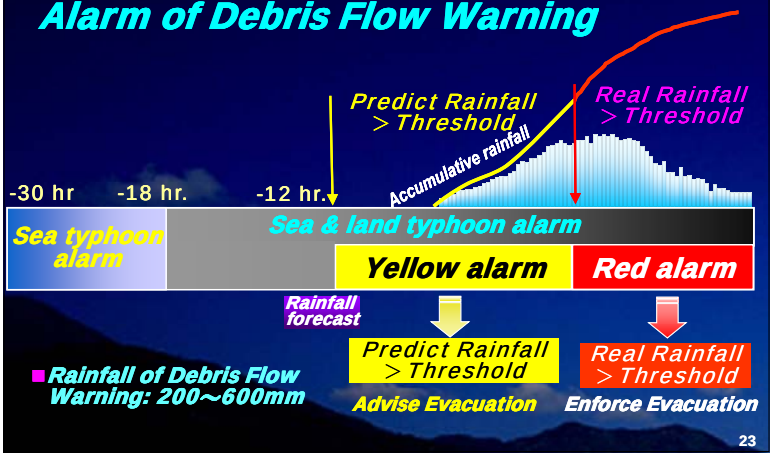
- The critical accumulated rainfall for evacuation (Rc) is set for easier public understanding and local application



22

Soil & Water Conservation Bureau

Alarm of Debris Flow Warning



- Rainfall of Debris Flow Warning: 200~600mm

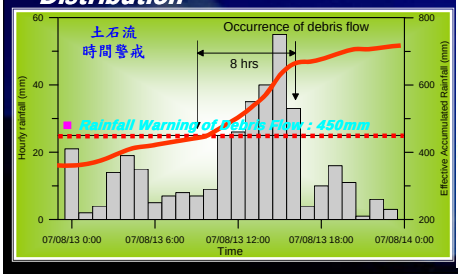
23

Soil & Water Conservation Bureau

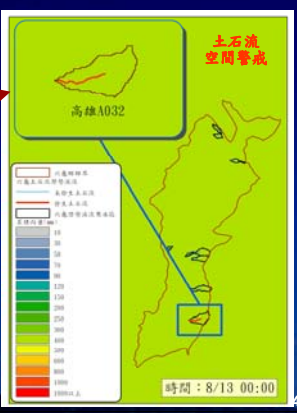
Time and Space Distribution of Rainfall Warning of Debris Flow Occurrence

Kalmaegi Typhoon, July 18, 2008

Time Distribution



Space Distribution



24

Effective Evaluation for Debris Flow Alert Operation

Evaluation Index

Factors	Functions	How to
Effective-ness of Alert Notice (C_1)	Check System Efficiency	$C_1 = A_1/D$ A_1: # happened after notice D: total # of debris flow
Accuracy of Threshold Values (C_2)	Check Reliability of Threshold Values	$C_2 = A_2/D$ A_2: # of acc. rainfall > alert value D: total # of debris flow
Accuracy of Alert Notice (C_3)	Check Accuracy of Alert System	$C_3 = A3/T$ A3: # villages that do suffering debris flow T: total # of warnings
Accuracy of Debris Alert (C_4)	Check Accuracy of Alert System	$C_4 = A4/T$ A4: # villages that do have debris hazards T: total # of warnings

Evaluation of 2008 and 2009

Events	C1(%)	C2(%)	C_3(%)	C_4(%)
Kalmaegi Typ. 2008	6 / 17 =35.3%	11 /17 =64.7%	5 / 36 = 13.9%	7 / 36 =19.4%
Honhung Typ. 2008	no debris flow	no debris flow	no debris flow	0
Sinlaku Typ. 2008	3 / 4 =75.0%	3 / 4 =75.0%	2 / 44 =4.6%	4 / 44 =9.0%
Jangmi Typ. 2008	no debris flow	no debris flow	no debris flow	0
2008 Average	55	69.9	9.25%	14.2%
Morakot Typ. 2009	24 / 28 =86%	24 / 28 =86%	10 / 61 =16.4%	18 /61 =29.5%
Parma Typ. 2009	1 / 1 =100%	1 / 1 =100%	1 / 7 =14.3%	2 / 7 =28.6%
1011 Storm 2009	no debris	no debris	no debris	no debris
2009 Average	93.2	93.2	15.4%	29.1%

In Japan, C1 is about 80%, C4 is about 30%
(高橋和雄，2006)

Soil & Water Conservation Bureau

Restrictions of Rainfall-based Debris-flow Warning Model & Solutions Thinking

Restriction A.
Debris flow events are not enough:
1. Establishment of debris flow events database.
2. Deployment of debris flow monitoring systems.
3. Correlation analysis between physiographical factors and rainfall-based debris flow warning criteria.

Restriction B.
Shortage of rainfall stations in the mountain area:
1. Enhance the spatial resolution of rainfall distribution using the QPESUMS
2. Distribute DIY rain gauges to local residents

Restriction C.
Uncertainty of the sequel rainfall:
1. Taking the QPESUMS rainfall prediction into consideration when issuing the debris flow warning

26

Soil & Water Conservation Bureau

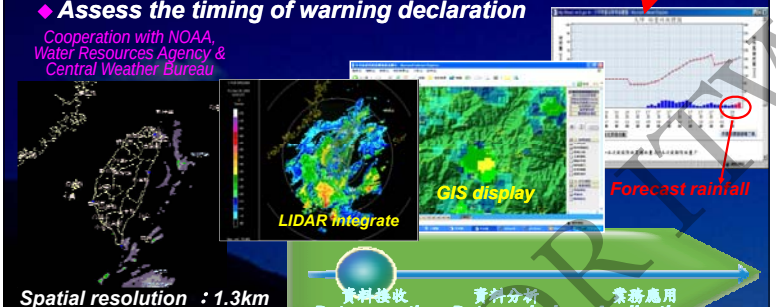
Apply QPESUMS for Rainfall Estimate

預測雨量整合

- Forecast 1 and 3 hour rainfall
- Data analysis: compute the rainfall value in the villages and rainfall stations
- Assess the timing of warning declaration

Shorten Evacuation time

Cooperation with NOAA, Water Resources Agency & Central Weather Bureau



Spatial resolution ：1.3km
Time resolution ：10min

27

Soil & Water Conservation Bureau

Evacuation Routes and Drills for Debris Flow Disaster Mitigation

- 548 Evacuation routes planned
- 552 debris flow evacuation drills held
- 800 Debris Flow Volunteer Specialists

Debris flow disaster mitigation volunteer

Evacuation routes

28

Soil & Water Conservation Bureau

Rainfall Cones DIY

➢ Distribute 21,000 DIY rain gauges to people.

President Ma v.s Debris Flow Volunteer Specialist

72水災遭土石流淹沒
但人員平安撤離

29

Soil & Water Conservation Bureau

Outdoor Classrooms for Soil & Water Conservation

22 locations
586,290 visitors/yr

Integrating communities with outdoor soil &water conservation classrooms

30

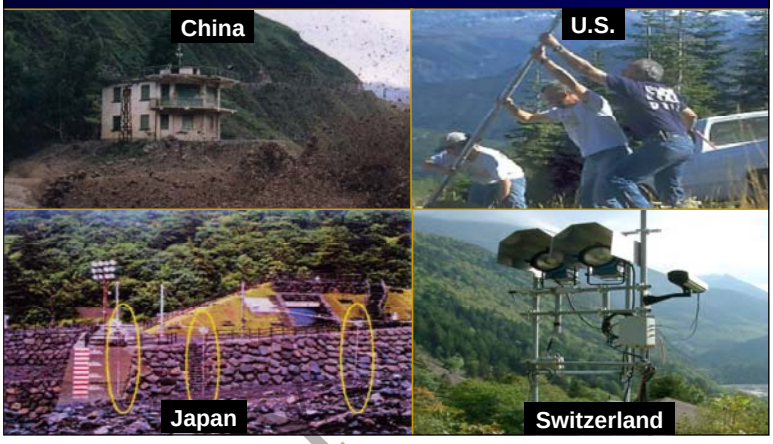
Soil & Water Conservation Bureau

Debris Flow Monitoring System

31

Soil & Water Conservation Bureau

Field debris flow monitoring



Soil & Water Conservation Bureau

Debris flow monitoring sensors

Non-contact type sensor

Rain gauge
Camera
Supersonic water level meter
Optical sensor
Vibration sensor

Contact type sensor

Wire sensor
Flipping sensor

33

Soil & Water Conservation Bureau

Debris flow monitoring system in Taiwan

✓Fixed (on-site) debris flow monitoring station x13(+4)
✓Mobile debris flow monitoring station x2(+1)

All the monitoring stations are established by SWCB (since 2002)

Soil & Water Conservation Bureau

Objective

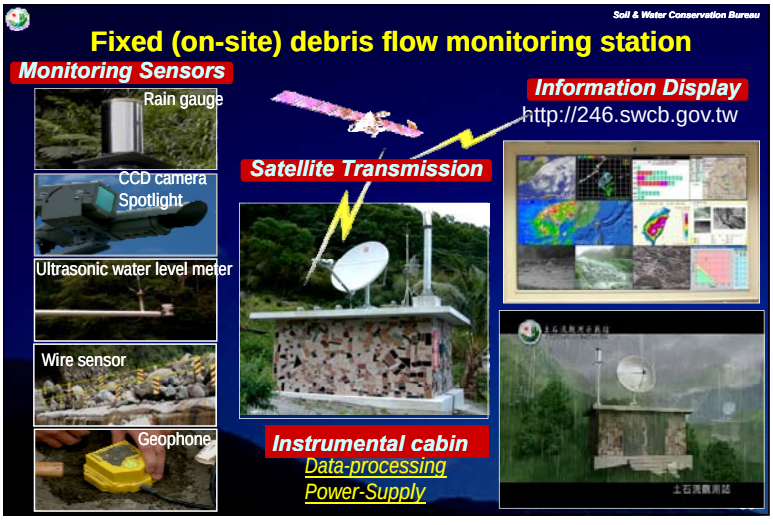
✓The debris flow monitoring stations are set up in order to obtain related information when the debris flow occurs.

✓All Observation data can be used as references for designing the countermeasures of debris flow disaster mitigation.

35

Soil & Water Conservation Bureau

Fixed (on-site) debris flow monitoring station



Soil & Water Conservation Bureau

Instrumental cabin—Data processing

- ✓IT System (Data processing)
  - ➢IPC(AD Card)
  - ➢DVR(VGA Card)
  - ➢Video server (IPC)
  - ➢Remote power controller
  - ➢Hub, Receiver



Soil & Water Conservation Bureau

Instrumental cabin—Power supply

Primary-domestic power supply

- ✓Backup(72 hr)
  - ➢UPS
  - ➢ATS
  - ➢Battery sets
  - ➢100L fuel tank
  - ➢Diesel generator



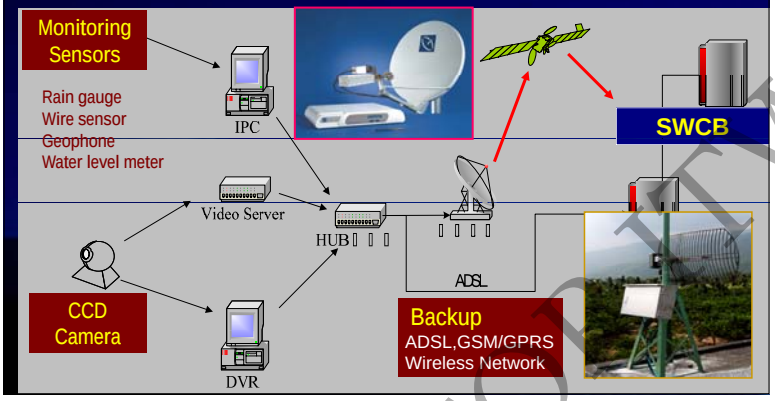


Soil & Water Conservation Bureau

Transmission system—Primary, Backup

Primary-VSAT satellite

Frequency：C band (3.95-8.2GHz)
Transmission rate：256 k/sec



Soil & Water Conservation Bureau

Web-based real-time display system

http://246.swcb.gov.tw

Soil & Water Conservation Bureau

Characteristics of debris flow monitoring system

	Dormancy stage		Operation stage
Operation mode	Normal mode	10mm/hr or 100mm or compulsion →	Event mode

Rainfall thresholds

Remote control

- Switch operation mode of system
- Zoom in / zoom out — CCD camera
- Rotate lens — CCD camera
- Turn on / off — spotlight
- Reset industrial computers

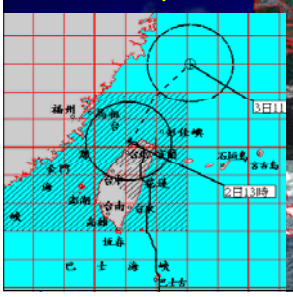
Open system

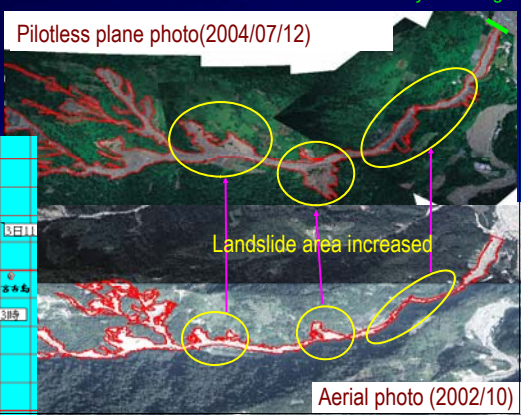
Future expansion of monitoring sensors

Soil & Water Conservation Bureau

Field Observation Data

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

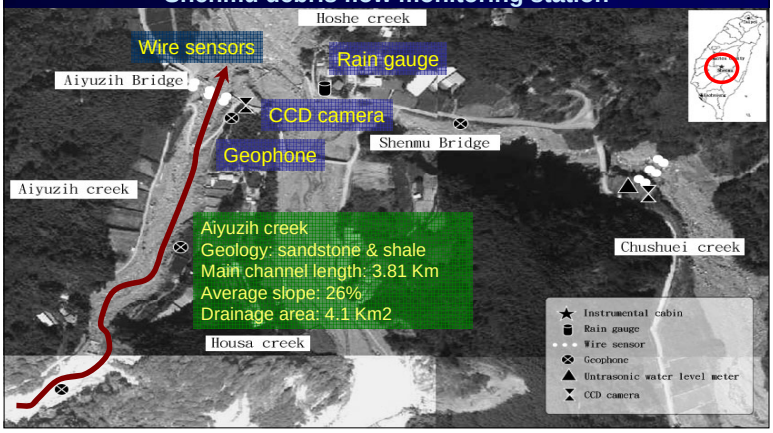




Soil & Water Conservation Bureau

Allocation of monitoring instruments

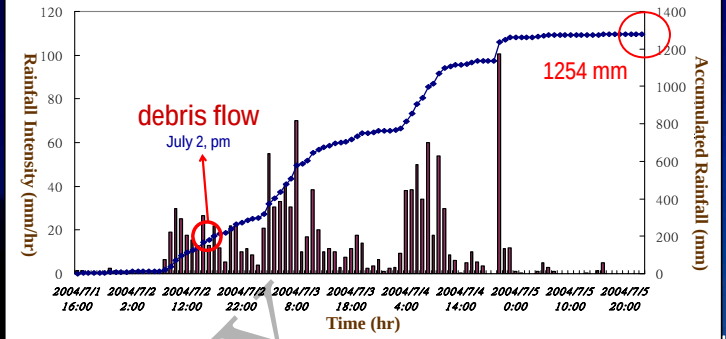
Shenmu debris flow monitoring station



Soil & Water Conservation Bureau

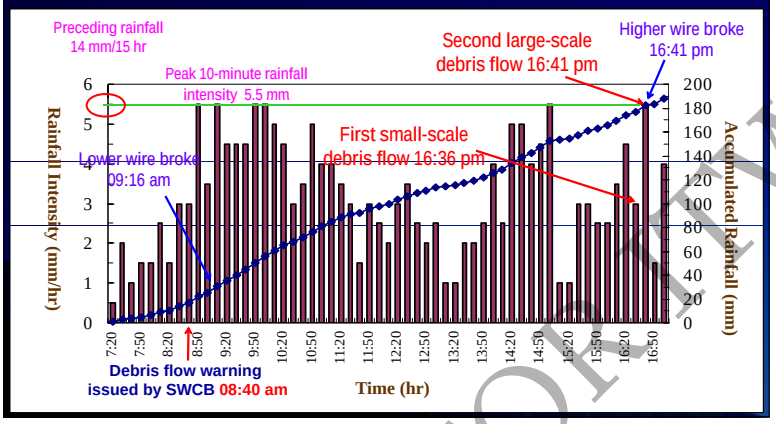
Field observation data

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



Soil & Water Conservation Bureau

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



Soil & Water Conservation Bureau

Characteristics of debris flows form image data

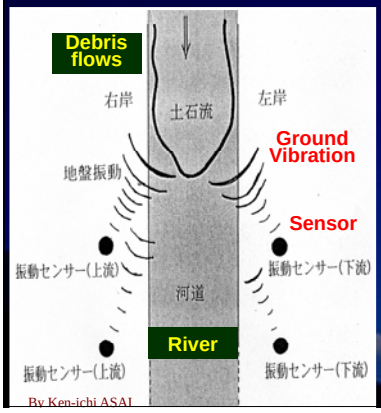
1. A very low discharge just before the surge
2. Accumulation of large boulders at debris flow front
3. Wavy surface of debris flows
4. A rapid decrease of the flow depth behind the front

- 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

46

Soil & Water Conservation Bureau

Ground vibration generated by debris flow

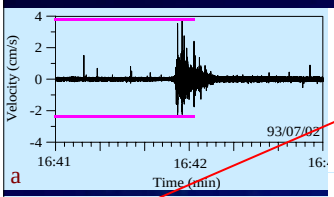


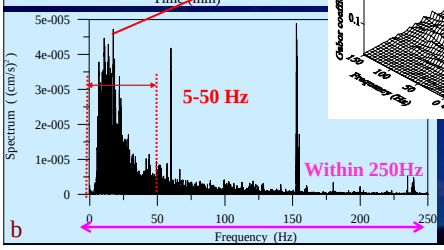
- During the debris flows, one can hear a roaring sound and experience ground vibration (or so called underground sound).
- → New way for early warning of debris flows occurrence.

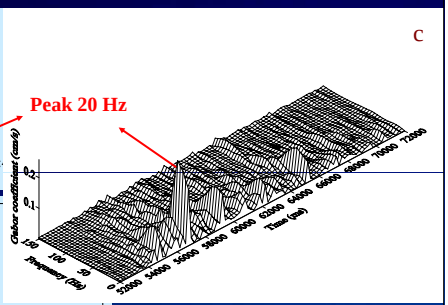
47

Soil & Water Conservation Bureau

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

48

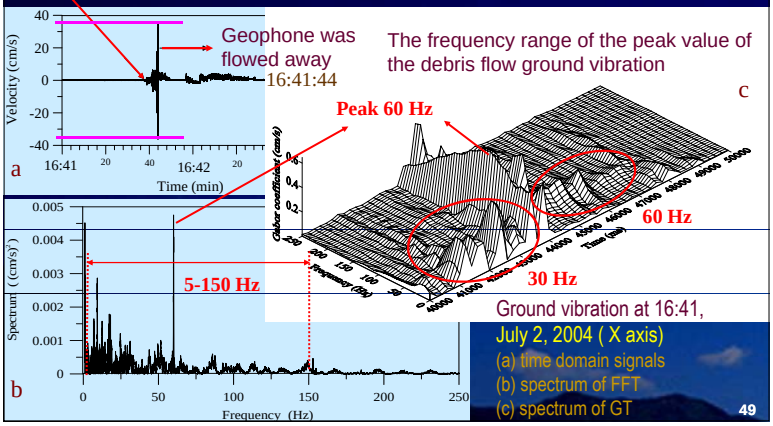
Soil & Water Conservation Bureau

Ground vibration of debris flow detected by midstream geophone

The starting point of ground vibration 16:41:37

Geophone was flowed away 16:41:44

The frequency range of the peak value of the debris flow ground vibration



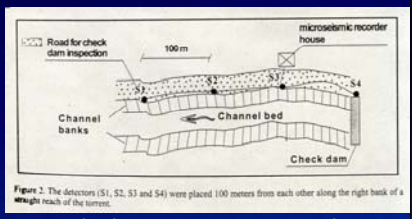
Ground vibration at 16:41, July 2, 2004 (X axis)
(a) time domain signals
(b) spectrum of FFT
(c) spectrum of GT

49

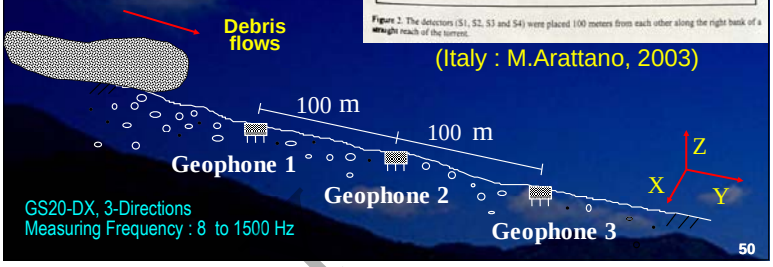
Soil & Water Conservation Bureau

Deployment of serial geophones

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



(Italy : M.Arattano, 2003)

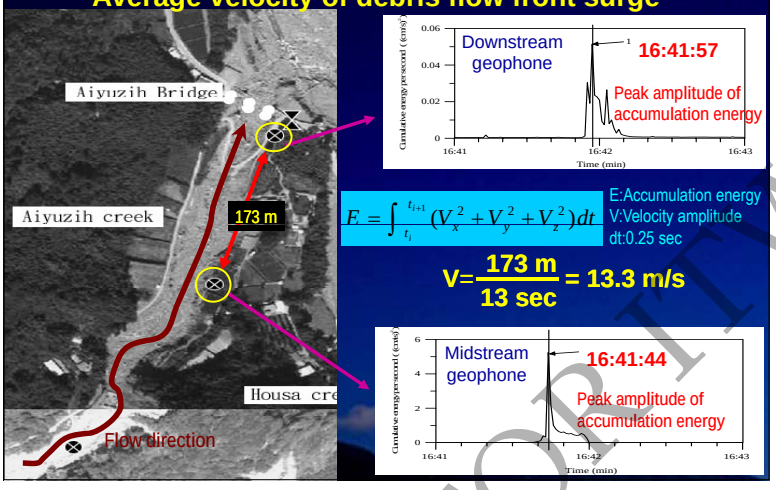


GS20-DX, 3-Directions
Measuring Frequency : 8 to 1500 Hz

50

Soil & Water Conservation Bureau

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

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

Soil & Water Conservation Bureau

Comparison of ground vibration velocity generated by debris flows

Midstream geophone: dry masonry bank revetment
Downstream geophone: concrete bank revetment

Geophone Location	Ground vibration velocity (cm/s)			Ratio against the background noise		
	X-axis	Y-axis	Z-axis	X-axis	Y-axis	Z-axis
Midstream	73	72	37.2	365	360	186
Downstream	6.47	5.13	4.58	32.35	25.65	22.9

52

Soil & Water Conservation Bureau

Criteria of detecting debris flow using ground vibration signal

- ✓The **amplitude** of ground vibration signal
- ✓The **time duration** of the signal over a certain threshold
- ✓The **frequency range** of the ground vibration signal

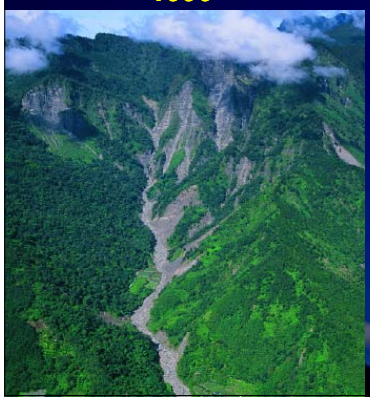
53

Soil & Water Conservation Bureau

Images from Unmanned Aerial Vehicle (UAV)

(Aiyuzih creek)

1996



2009

Soil & Water Conservation Bureau

Videos from UAV after Typhoon Morakot, 2009 (Aiyuzih creek)

Soil & Water Conservation Bureau

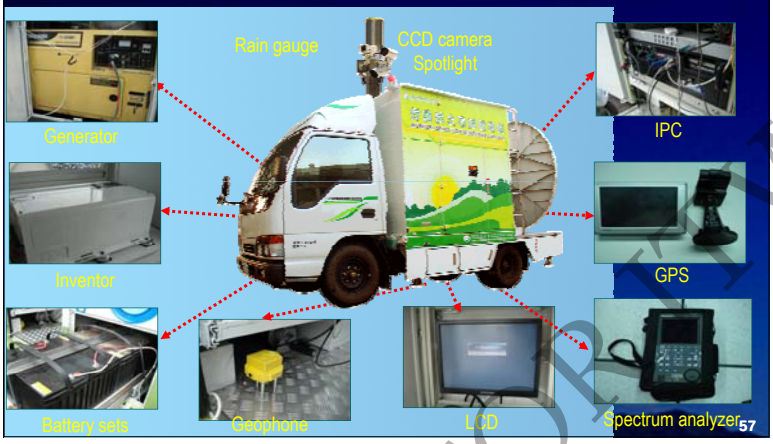
Monitoring Images – Aiyuzih Creek Shenmu Station during Typhoon Morakot, 2009

Downstream CCD image (front view) | Midstream CCD image (side view)

Front surge velocity 50m/3sec=17m/s

Soil & Water Conservation Bureau

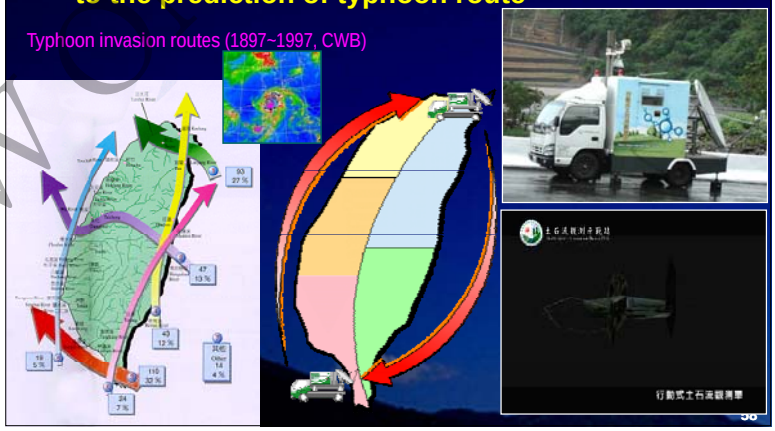
Development of mobile debris flow monitoring station (since 2004)



Soil & Water Conservation Bureau

Dispatch of mobile stations according to the prediction of typhoon route

Typhoon invasion routes (1897~1997, CWB)



Soil & Water Conservation Bureau

Real time monitoring of dammed lake

(4 million m^3 of water storage)

July 23, 2006

Lung-Chuen stream, Taitung County (eastern Taiwan)

Soil & Water Conservation Bureau

Future development— module of monitoring sensors

Broaden the observation scope

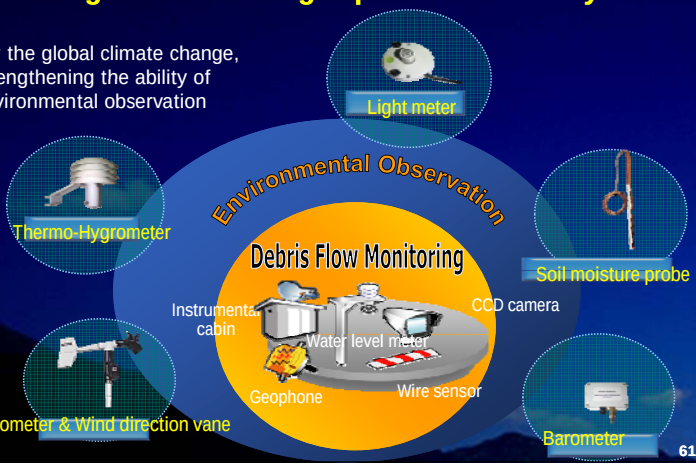
Rain gauge

CCD camera

Soil & Water Conservation Bureau

Strengthen monitoring capabilities of the system

- For the global climate change, strengthening the ability of environmental observation

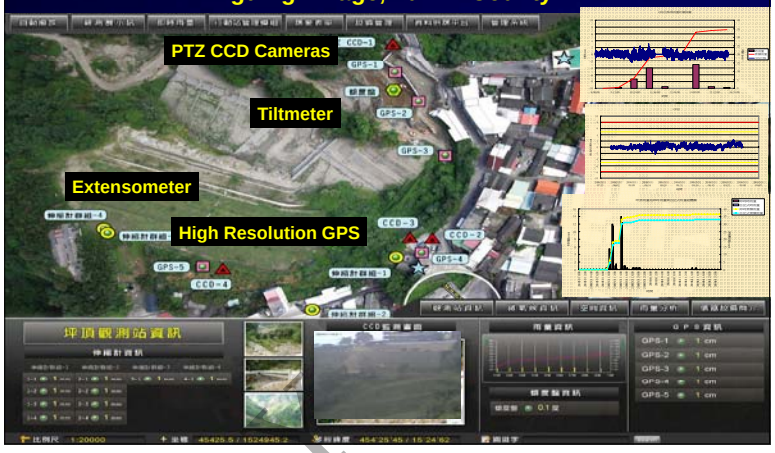


61

Soil & Water Conservation Bureau

Landslide Monitoring Station (since 2008)

Pingding Village, Yunlin County



Soil & Water Conservation Bureau

Shimen Reservoir Watershed Sediment Monitoring Station (since 2008)

Data Receive Center

Monitoring Instruments

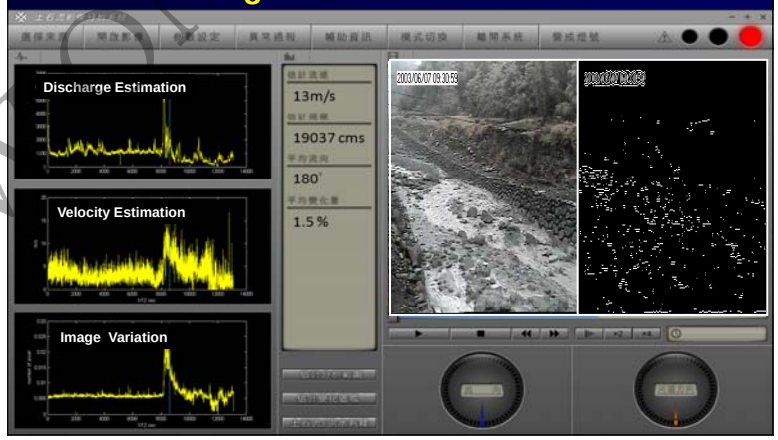
CCD Cameras

Water level meter Water pressure meter Earth pressure meter

63

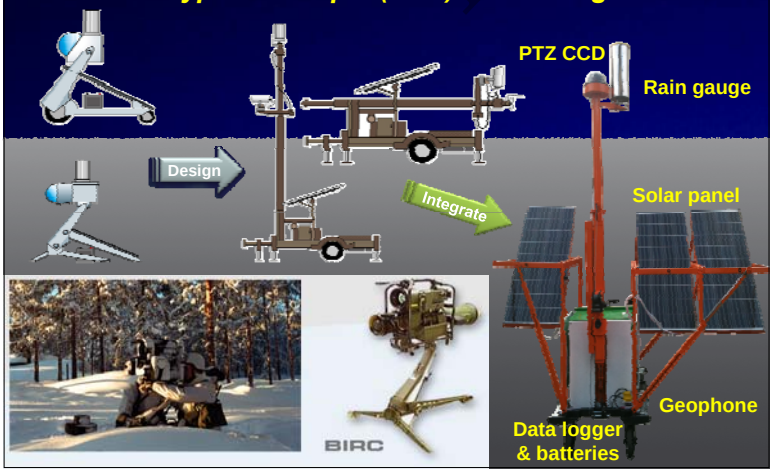
Soil & Water Conservation Bureau

Automatic Analysis System of Images from CCD Camera



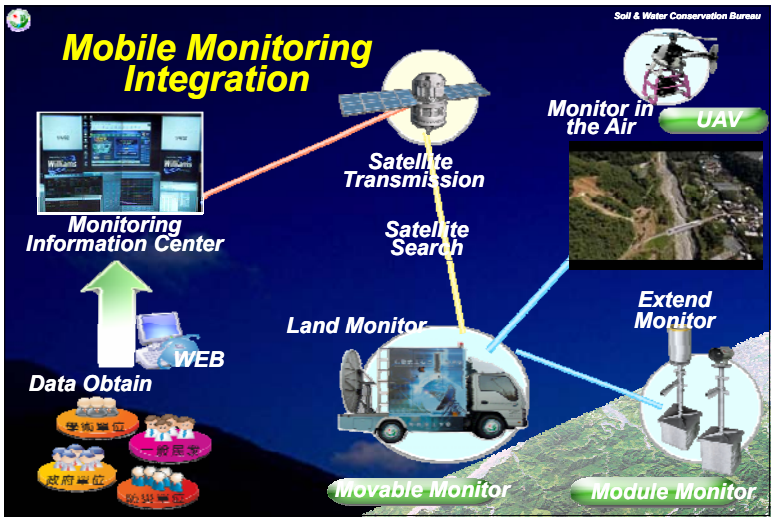
Soil & Water Conservation Bureau

Prototype of Simple (Grid) Monitoring Station

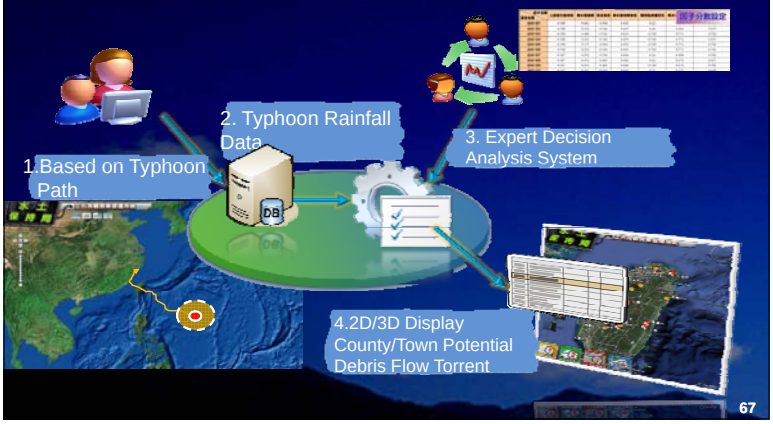


Soil & Water Conservation Bureau

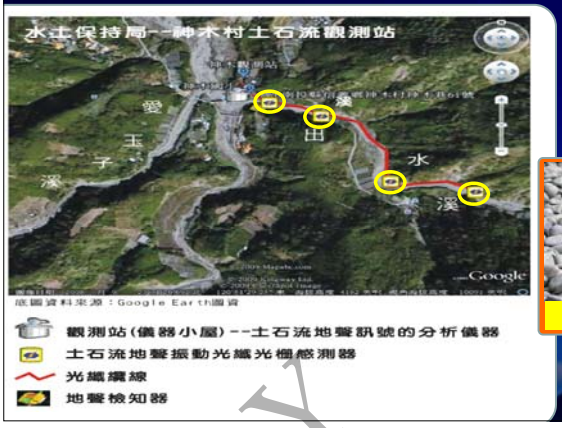
Mobile Monitoring Integration



Debris Flow Monitoring and Forecast System– Mobile Station Dispatch System



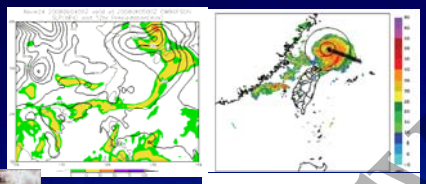
Application of Optical Fiber to Ground Vibration Detection

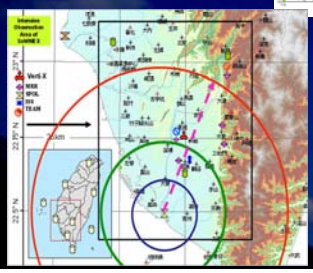


Broaden the upstream monitoring area (about 1.3 kilometers)

✓Fixed & Mobile Doppler Weather Radar Stations

The SWCB cooperate with Central Weather Bureau (CWB) to develop the radar echo technology in rainfall predictions.



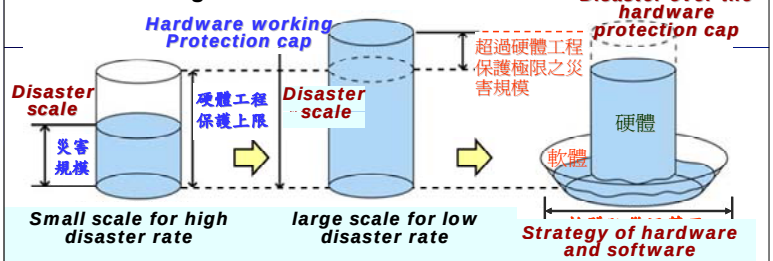


Debris Flow Disaster Recovery Hua-shan Village

-Case Study-

Software Combination with Hardware for Disaster Mitigation

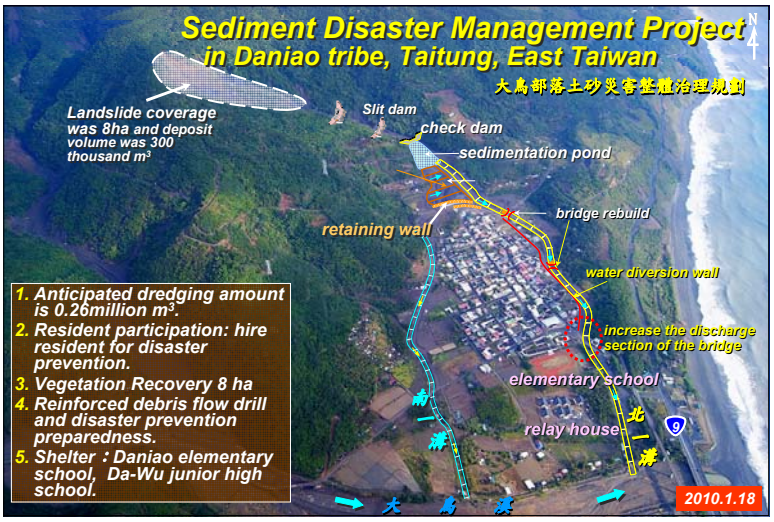
- *Under climate change impact, strategy of disaster precaution should be considered from software to hardware.*
- *Non-engineering measures should combine with mitigation works.*



(摘自日本地方再生戰略，2008)

Sediment Disaster Management Project in Daniao tribe, Taitung, East Taiwan

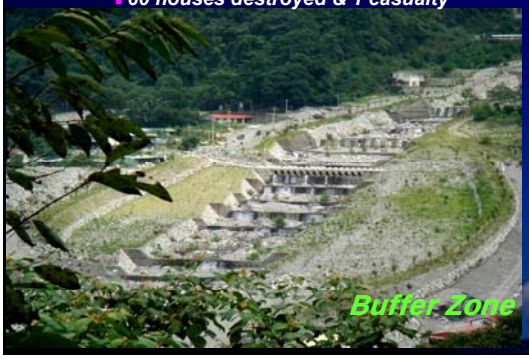
大鳥部落土砂災害整體治理規劃



Soil & Water Conservation Bureau

Debris Flow Disasters & Mitigation Porject
after Typhoon Mindulle (2004/7/2) in Sungho, Taichung

- Rainfall accumulated: 1,430mm
- Sediment yield: 250000m³
- Evacuated 1080 residents
- 60 houses destroyed & 1 casualty



After Chichi Earthquake

After Typhoon Mindulle

73

Soil & Water Conservation Bureau

Integrated Reservoir Watershed Conservation & recovery Project in Su-Le

Debris flow disaster
2005.2.26 15:01

After Restoration 2006.6.09 storm

公路局復興工務段提供

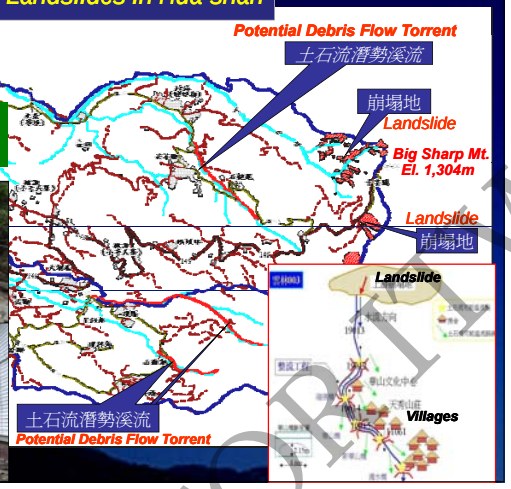
Before → After recovery

74

Soil & Water Conservation Bureau

Debris Flow Torrents & Landslides in Hua-shan

- 15 houses, 1 road & 3 bridges destroyed by debris flows in 2000 and 2001



Soil & Water Conservation Bureau

Deployment of engineering works in Hua-shan

76

Soil & Water Conservation Bureau

Landslide Source Stabilization by Local Residents
Filling cracks, staking, drainage system

77

Soil & Water Conservation Bureau

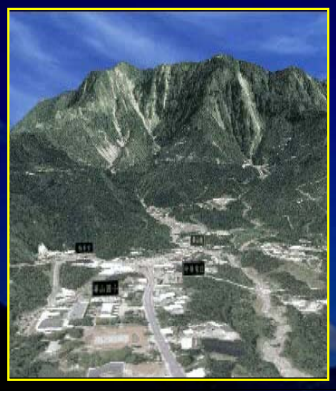
Case Study

台灣咖啡的故鄉

Debris Flow Disaster Mitigation Combined with Rural Development
In Hua-shan, Kukeng, Yunlin

After Nari Typhoon
2001.09.18

Mergence of Business & Ecology



Debris flow monitor

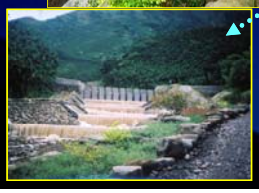
78

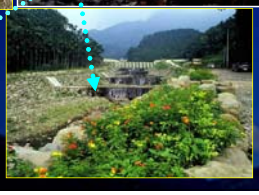
Soil & Water Conservation Bureau

Debris Flow Outdoor Classroom Established after Debris Flow Mitigation

in Hua-shan, Ku-keng, Yunlin

Value-added Benefit





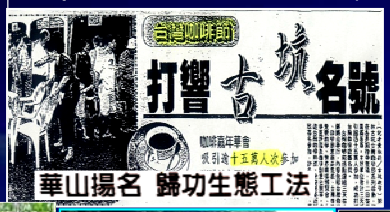
79

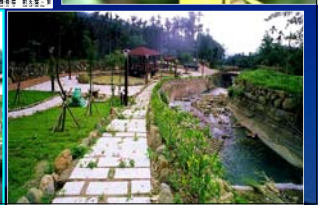
Soil & Water Conservation Bureau

2004 Coffee Festival

—The name of "Hometown of Taiwan Coffee" spreads all over the whole country.

With NT$ 3 millions expanses in promotion, the villagers earned over NT$ 400 millions.



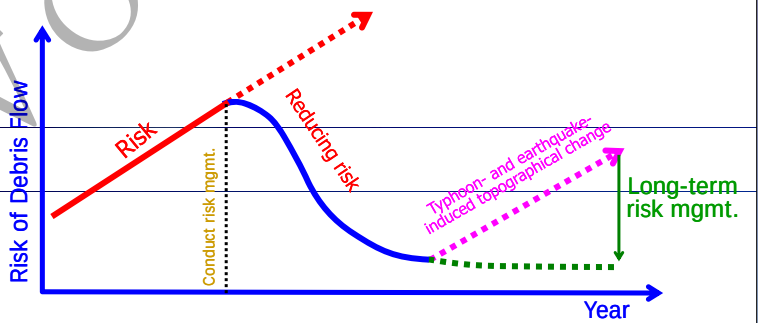


華山經典農村

Award the Top 10 Rural Villages

Debris Flow Disaster Mitigation with Integrated Rural Development in Hua-shan, Ku-keng, Yunlin

Effects and Expectation from Risk Management



(modified from Hong Kong GEO)

Soil & Water Conservation Bureau

Future Perspective for Debris Flow Disaster Management

—T.H.I.N.K—

- Technology：Research, development and practice.
- Human management：Improve people's knowledge 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.

83

Thank You for Attention

Soil and Water Conservation Bureau
Always Working with You