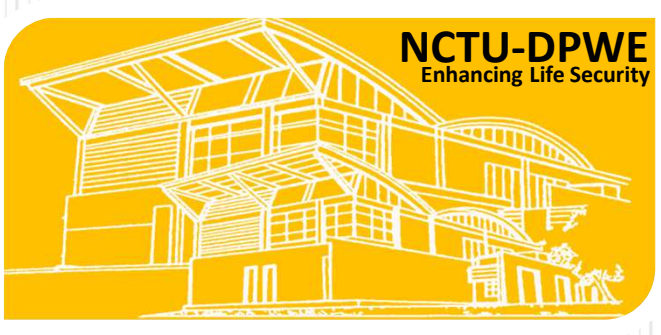
Sustainable Reservoir Strategy and Flood Management in Taiwan



Prof Jinn-Chuang Yang
National Chiao Tung University
Disaster Prevention and Water Environment Research Center

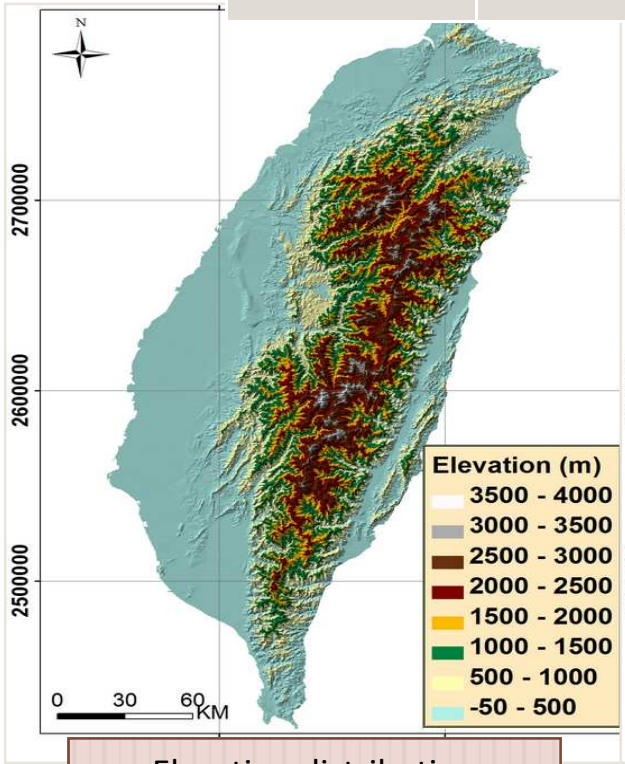
Outlines

- Natural Environment in Taiwan
  - Landform, geology, & hydrology
  - Water related disasters
  - Short summary
- Sustainable Reservoir Strategy
- Flood management
- Collaboration with Deltares

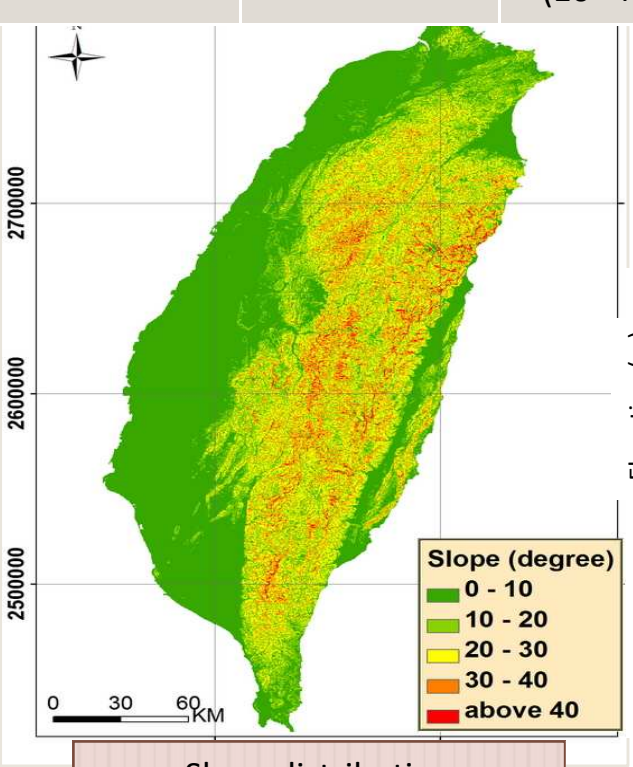
Natural environments in Taiwan

- Landform and geology

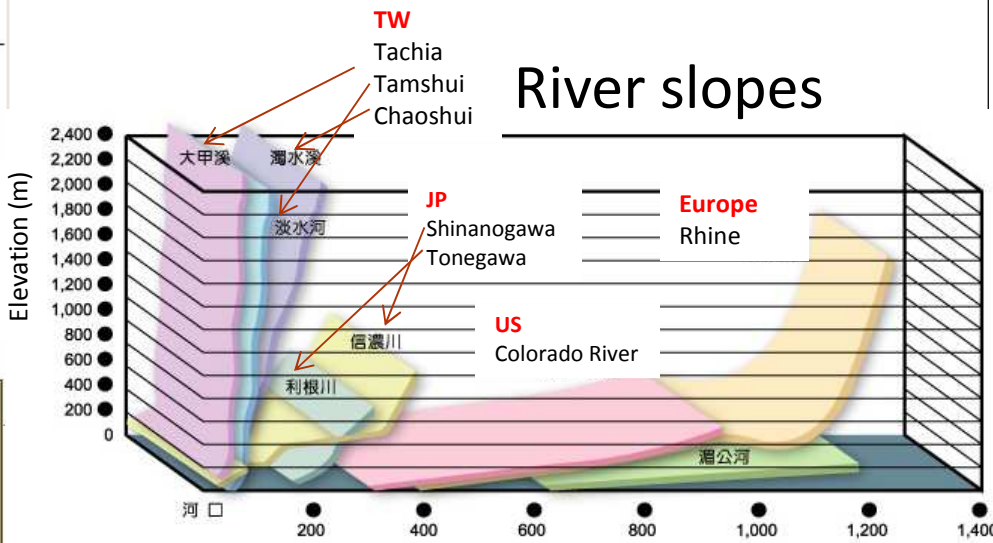
Total area	Mountainous area	Population	Population density
36,000 km^2	66%	23 M	639 per km^2 (10th highest over the world)



Elevation distribution



Slope distribution

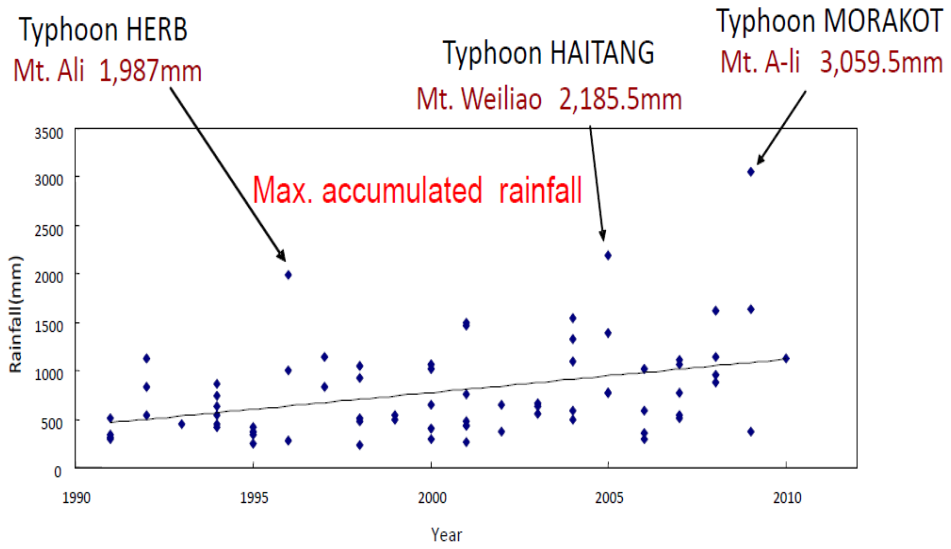


Distance from the river mouth (km)

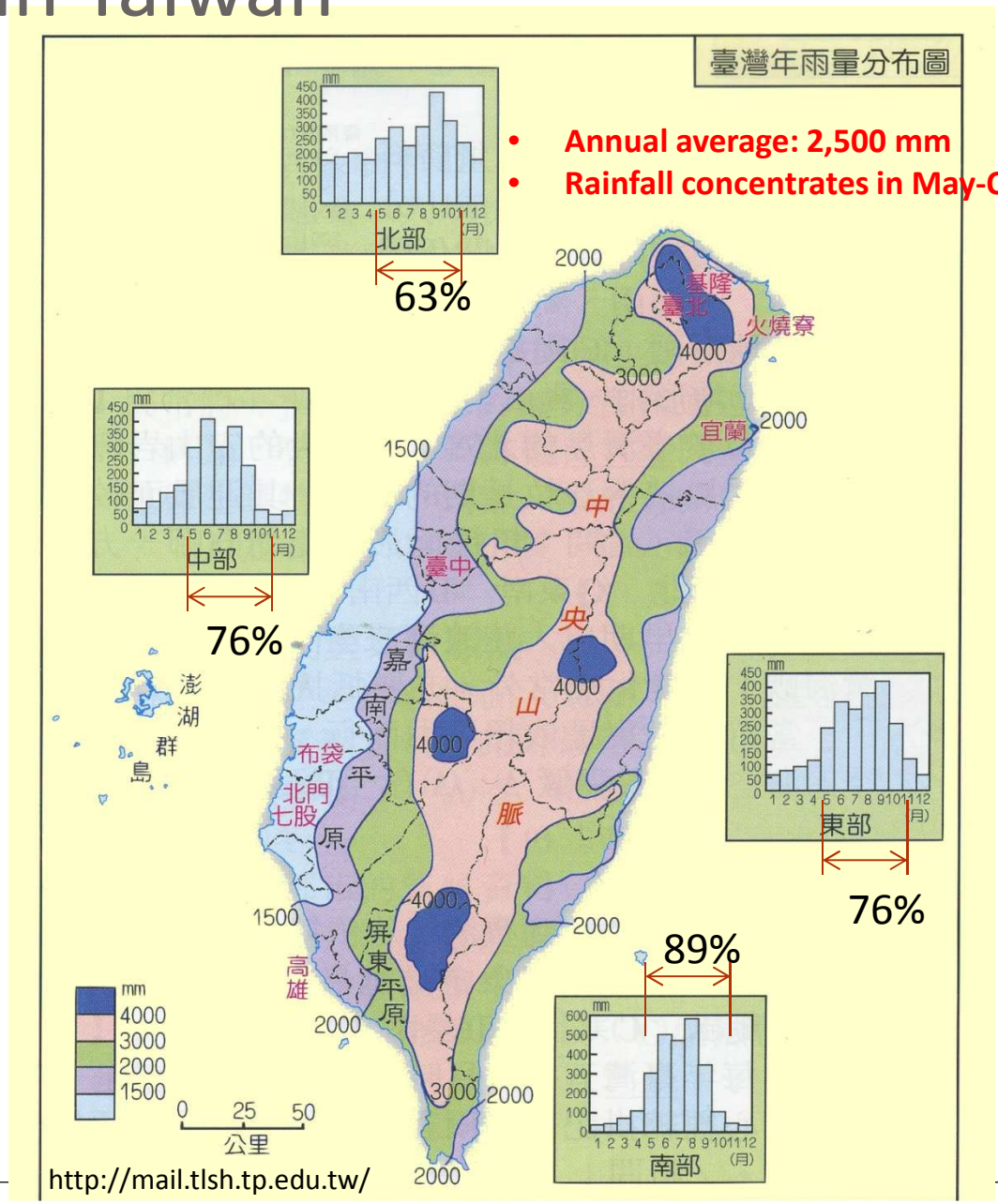
From: WRA

Natural environments in Taiwan

Hydrology



- Wet season - Rainfall induced landslide in watershed
  - Reservoir sediment deposition ➡ Storage capacity loss
  - Turbid water ➡ Clean water shortage
- Dry season - Water demand
  - Reservoir water supply meet 30% of water demand
  - Groundwater abstraction meet 20%-40% of water demand ➡ Landsubsidence



- **Annual average: 2,500 mm**
- **Rainfall concentrates in May-Oct**

Rainfall induced disasters

圖片來源：水保局網頁

Landslide and Debris Flow


圖片來源：農委會林務局(2006)

Watershed

Reservoir

Degraded ecological environment

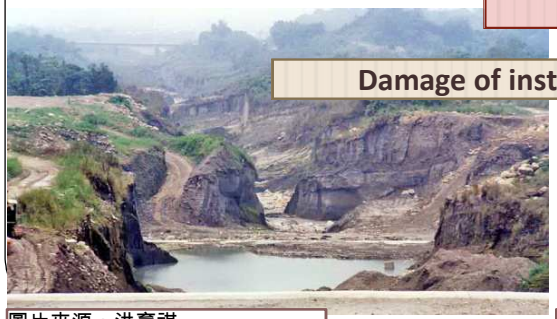

圖片來源：FISRWG (1998)

Overflowing


圖片來源：網頁新聞畫面

River instream

Urban Area



圖片來源：洪夢祺


圖片來源：網頁新聞畫面

Land Subsidence


圖片來源：地層下陷防治服務團

Inundation


圖片來源：網頁新聞畫面

Landslide disasters

- Mountain village
  - 2009 Typhoon Morakot doomed Xiaolin Village

Landslide volume > 20 M m^3
Casualty > 600

Flood disasters

2009 Typhoon Morakot

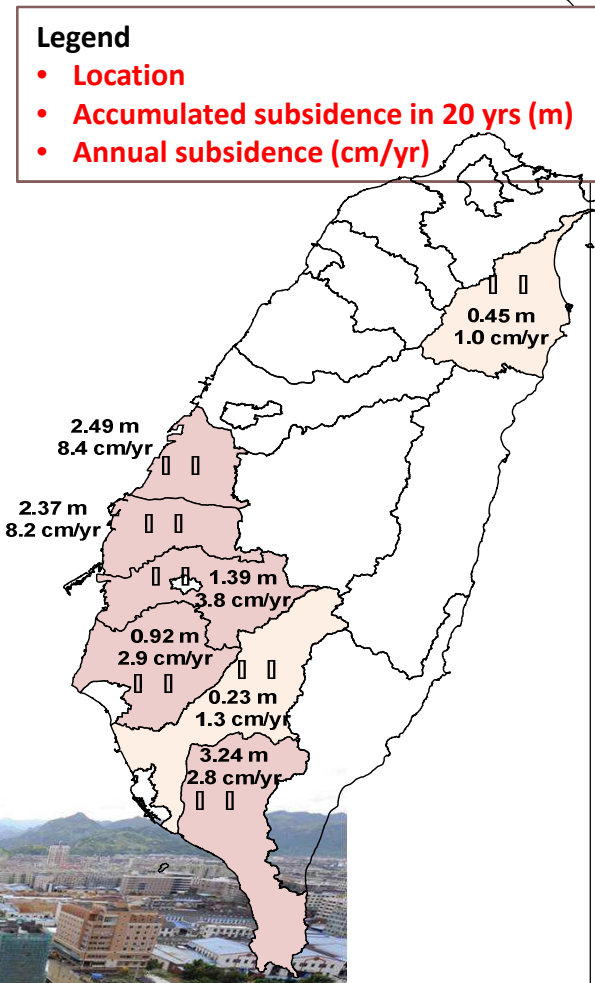
- Rapid river evolution in southeast Taiwan

Before

After

Disasters in subsidence area

- Inundation
- Sea water intrusion



Storage reduction in reservoirs

Reservoir	Completion	Total storage capacity (M m^3)	Capacity loss (M m^3)	Storage capacity loss
Feitsui	1987	344	57	14.5%
Shihmen	1963	251	99	32.1%
Wuseh	1958	146	96	64.0%
Baiho	1965	25	16	59.3%
Tsengwen	1973	631	257	34.4%
Nanhua	1993	149	62	39.0%
Wushanto	1930	103	45	35.7%
Agondian	1953	20	9.2	33.8%
Mutan	1995	31	3.6	11.4%

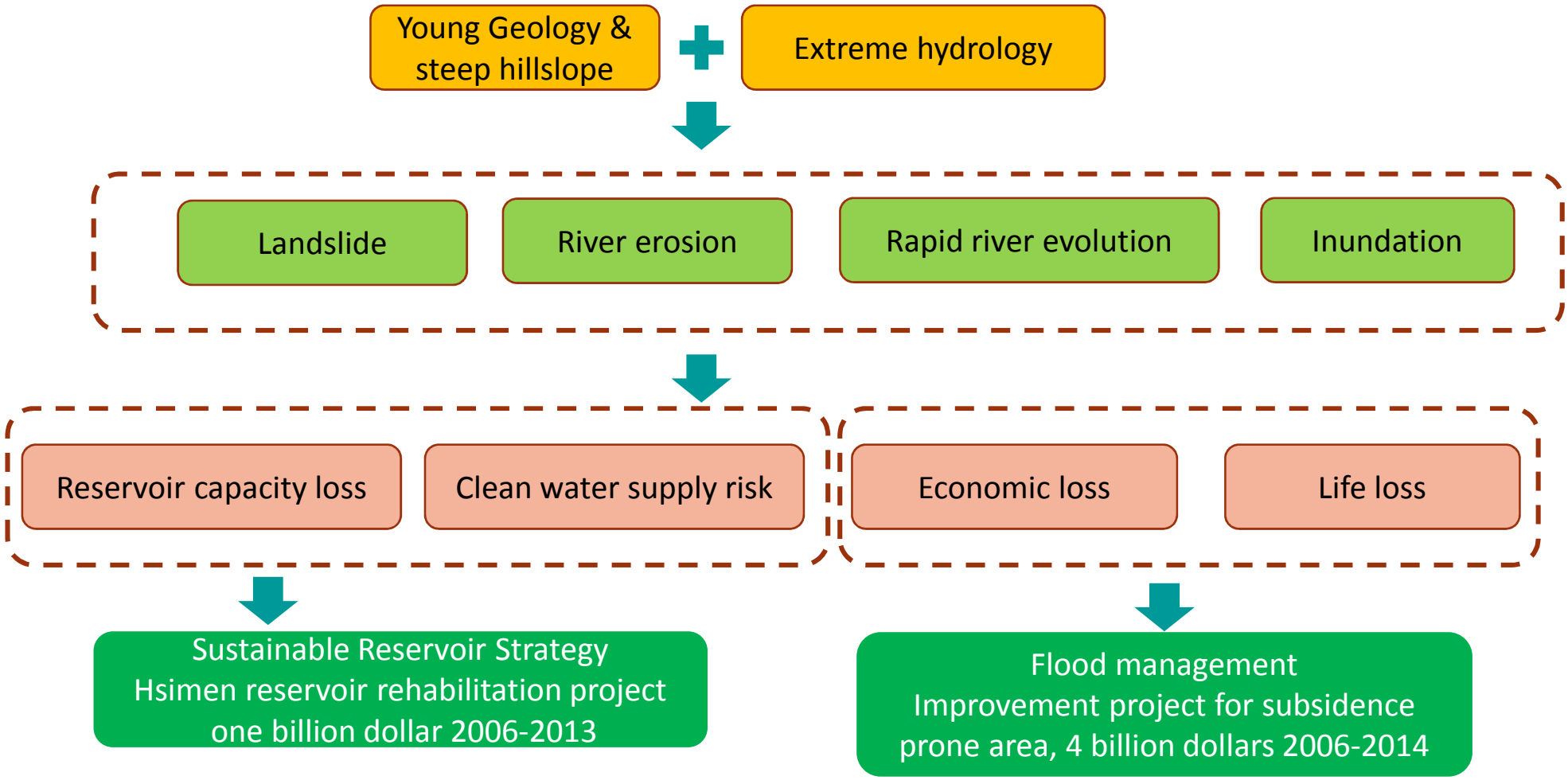
70% of all reservoirs storage

Averaged 36% of storage capacity loss

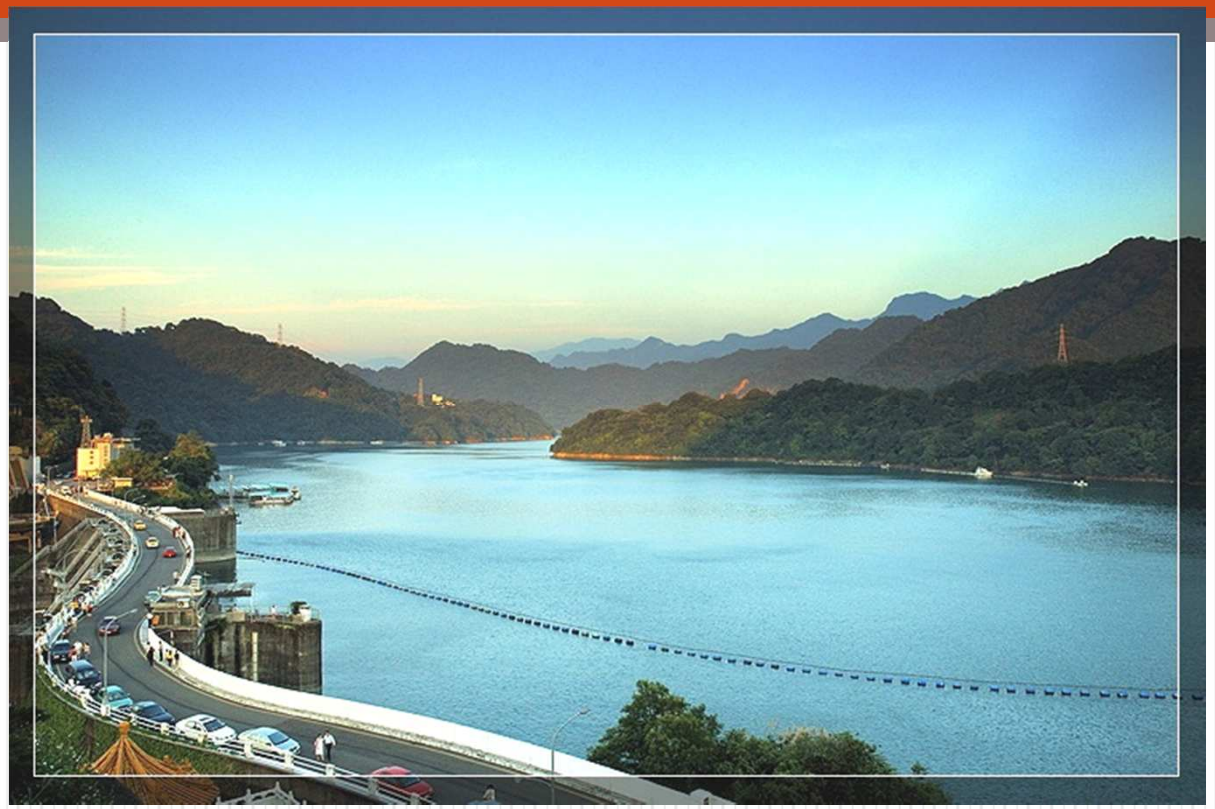
17% storage capacity loss in 2009 TP Morakot

12 M m^3 sediment dredging during 1997-2006

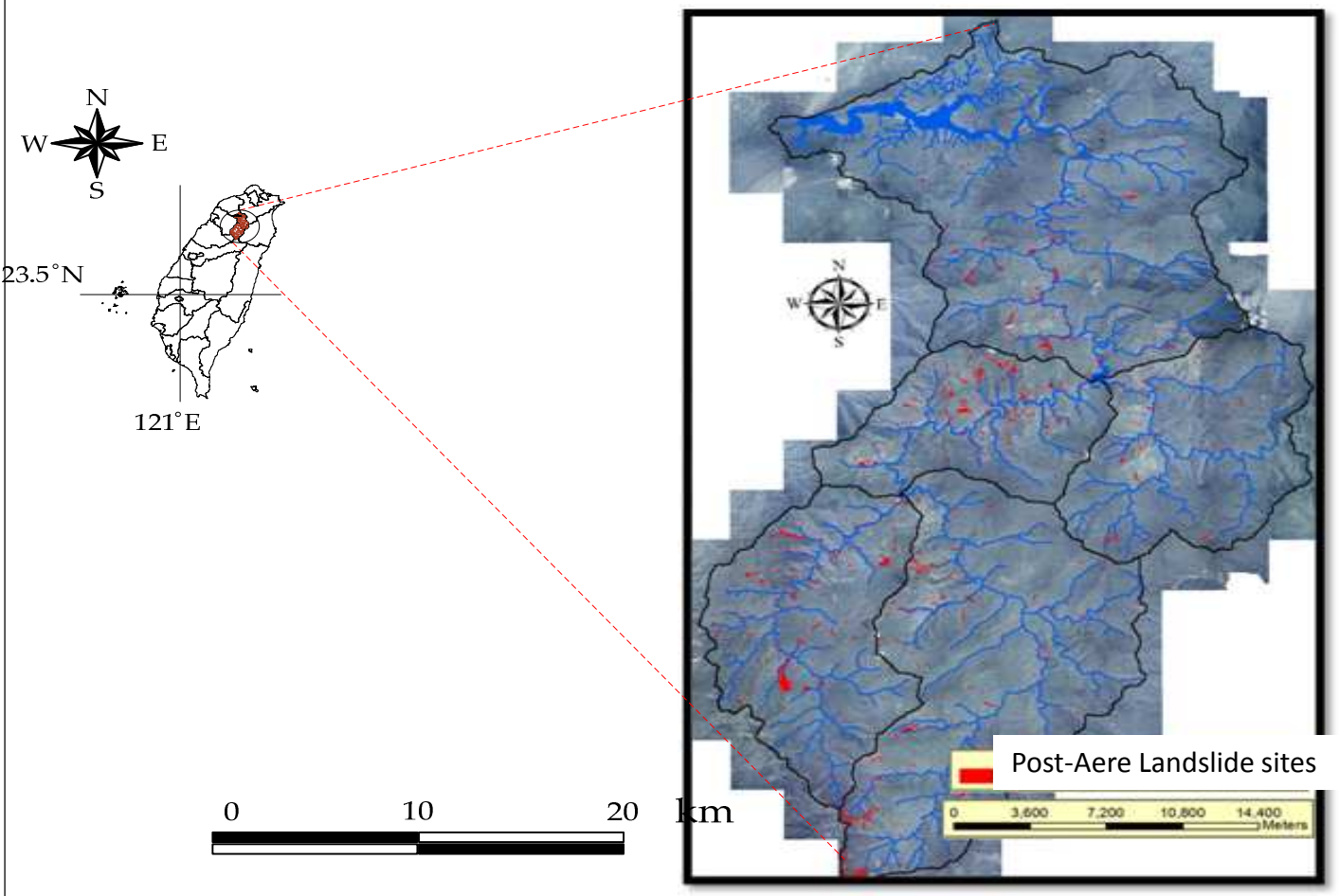
Short summary



Sustainable reservoir strategy
- Shihmen Reservoir



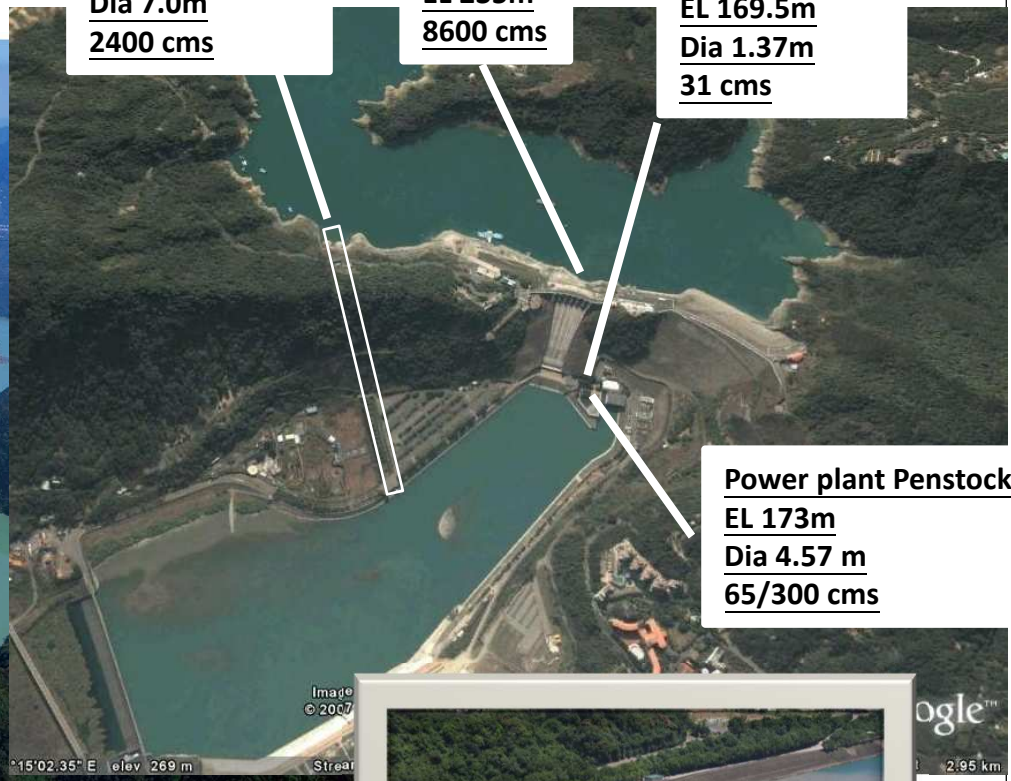
Brief info on Shihmen Reservoir watershed



- Watershed: 763.4 km^2
- Full water level: 245 m
- Dam Height:133 m
- Total storage: 309 M m^3
- Design effective storage: 251 M m^3
- Effective storage: 209 M m^3(in 2011)
- Lost 11% storage in 2004 Typhoon Aere

Facilities

Stratified water intake shaft



Tunnel spillways
EL 220m
Dia 7.0m
2400 cms

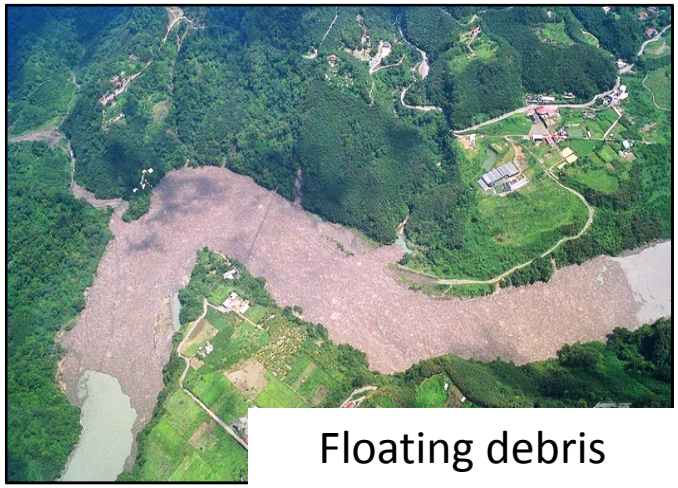
Spillways
EL 235m
8600 cms

PRO
EL 169.5m
Dia 1.37m
31 cms

Power plant Penstock
EL 173m
Dia 4.57 m
65/300 cms

From WRA website

Damages by 2004 Typhoon Aere



Floating debris

Turbid water >> 3000 ntu

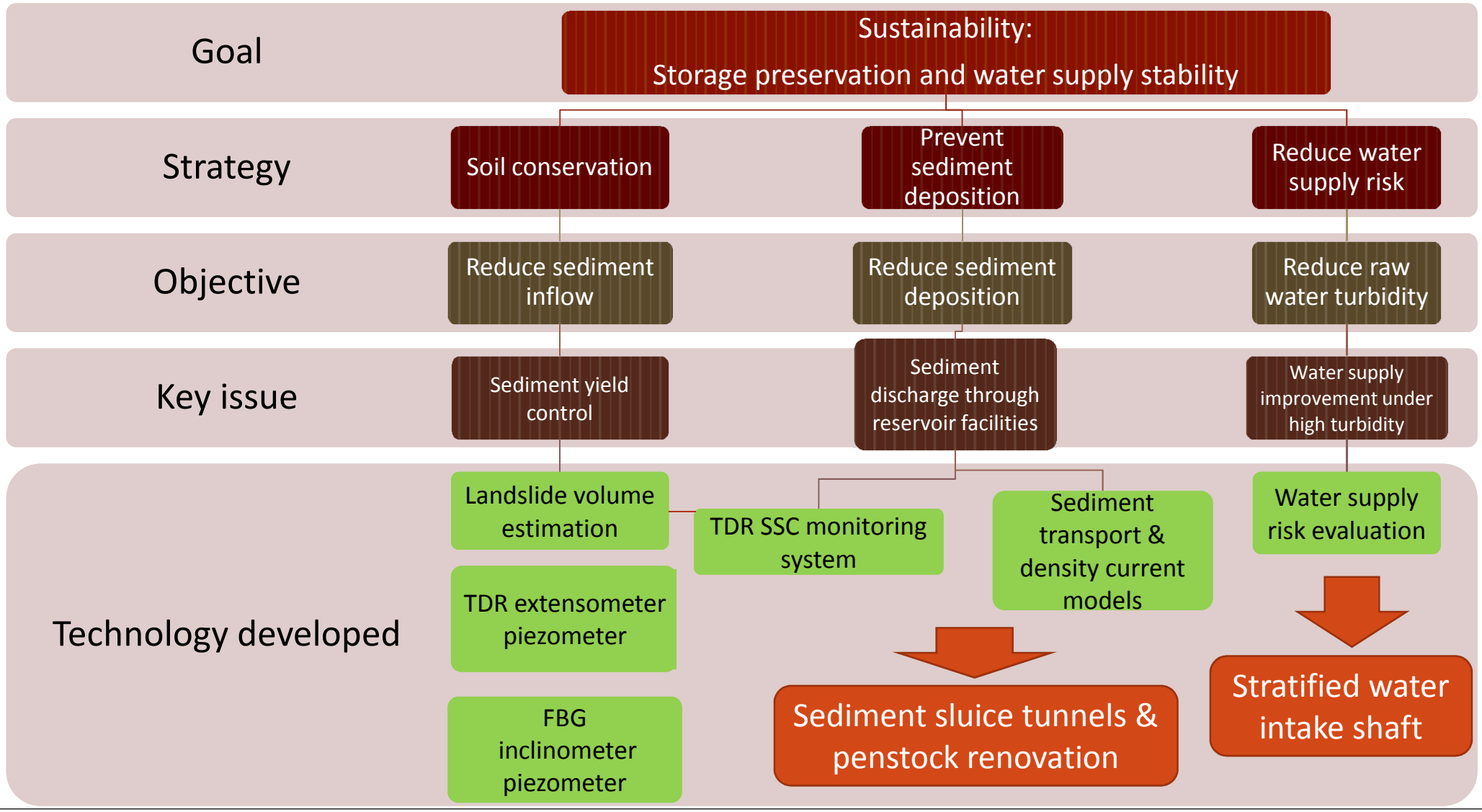
- 967 mm rainfall in area average
- 8600 cms of peak discharge
- 665 million m^3 of inflow vol.
  (3 times the effective capacity)
- Landslide area: 673 hectares
- Sediment deposition 27 M m^3
  (11% of design capacity)
- Water supply stopped for 18 days

Power plant valve

Turbine

Trash racks

Sustainable reservoir strategy and key technologies

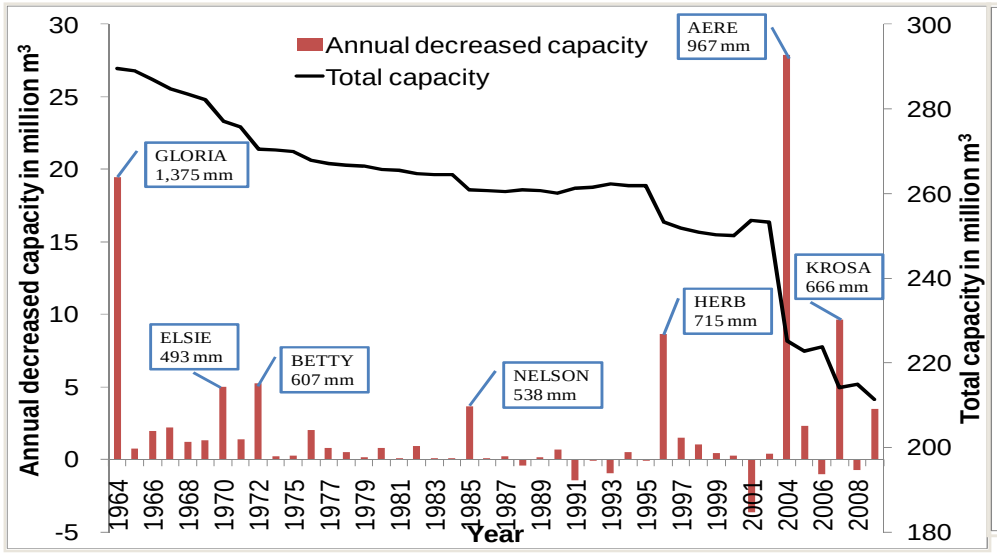


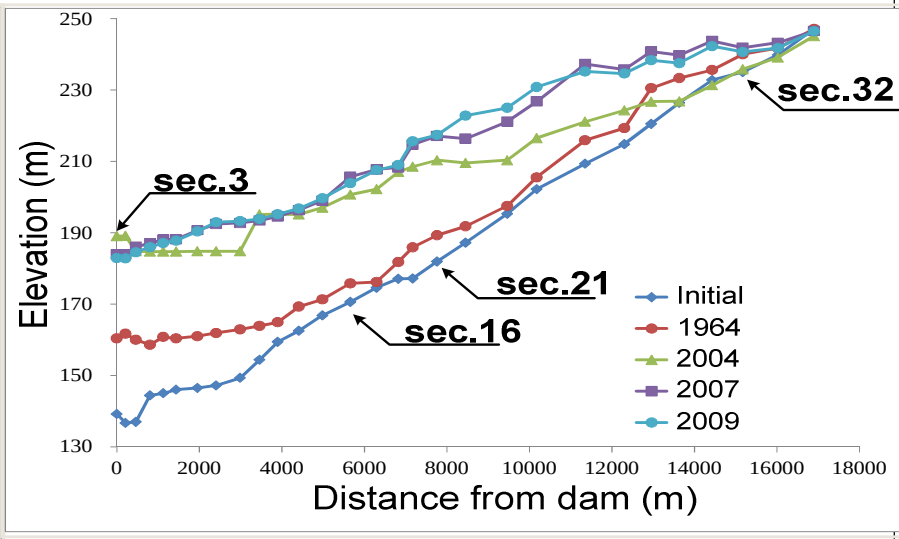
Landslide and reservoir sediment deposition

- Shihmen Reservoir
  - Decrease in capacity

Typhoon	Landslide area	Decreased capacity	Percentage of design capacity
2004 Aere	673 ha.	27×10^6 m^3	11%

  - Storage capacity history of Shihmen reservoir





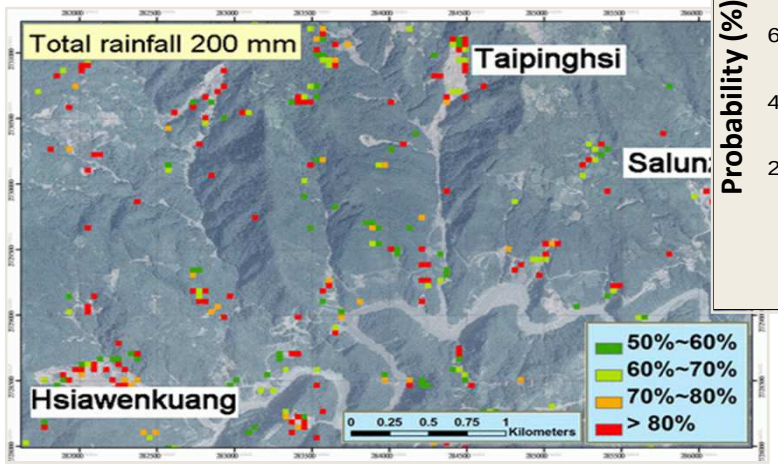
Sediment yield & reservoir deposition estimation

- Landslide volume estimation modeling

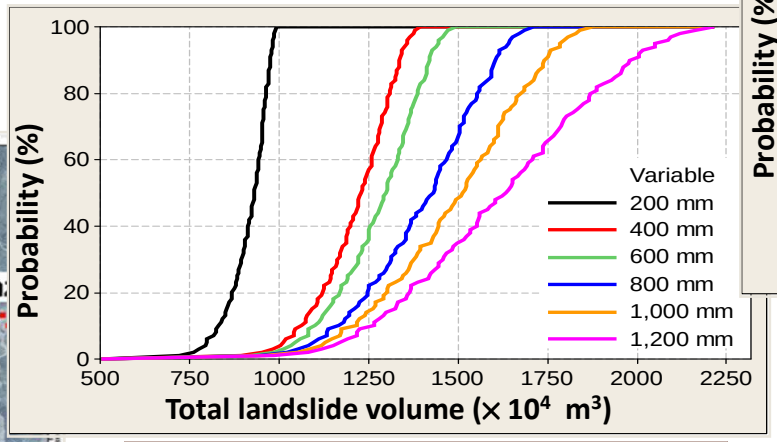
Sediment yield
&
reservoir deposition

Potential landslide volume

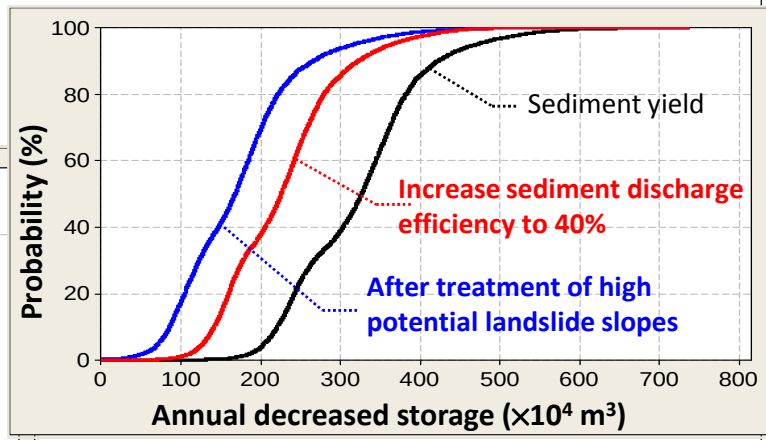
Potential landslide area



Landslide occurrence probability

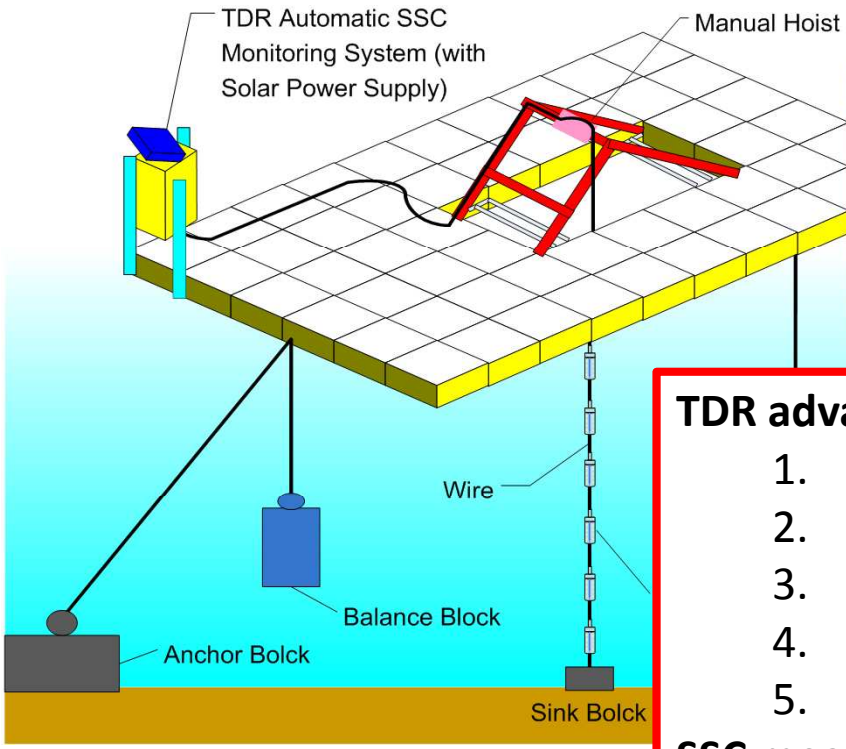


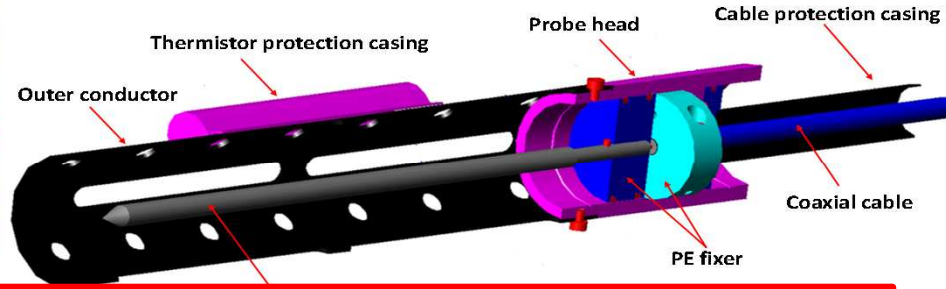
Landslide volume estimation conditional on rainfall amounts



Probability distribution of annual deposition

TDR SSC monitoring system



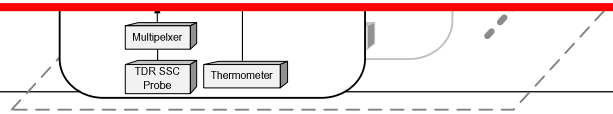


TDR advantages:

1. Transmission Line (like TV cable, cheap) mechanism based
2. Waveguides without any electronics
3. Easy installation and maintenance
4. Multi-function and multi-channel
5. (Semi-) profile scan in one cable

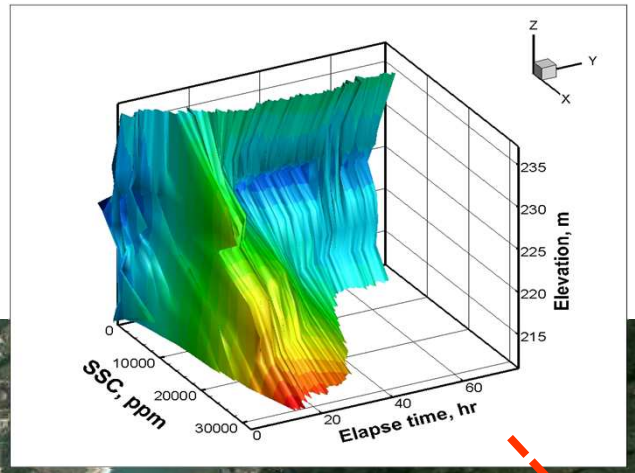
SSC measurement:

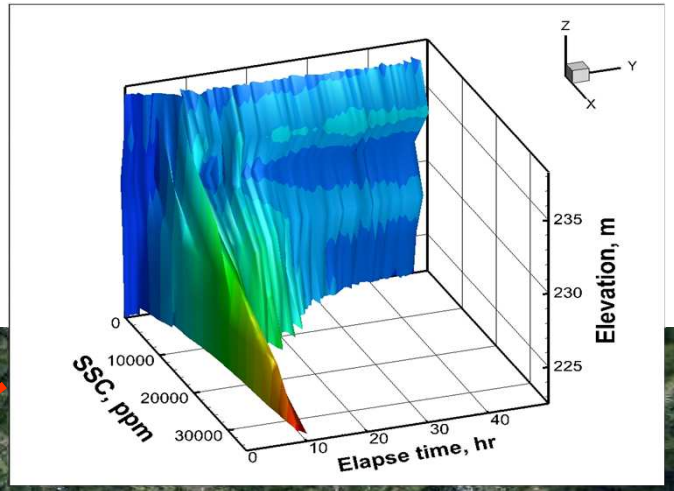
- Accuracy ~ ±1000 ppm
- Range from 1000 ppm to >300,000 ppm
- Particle size independent
- Error <15%

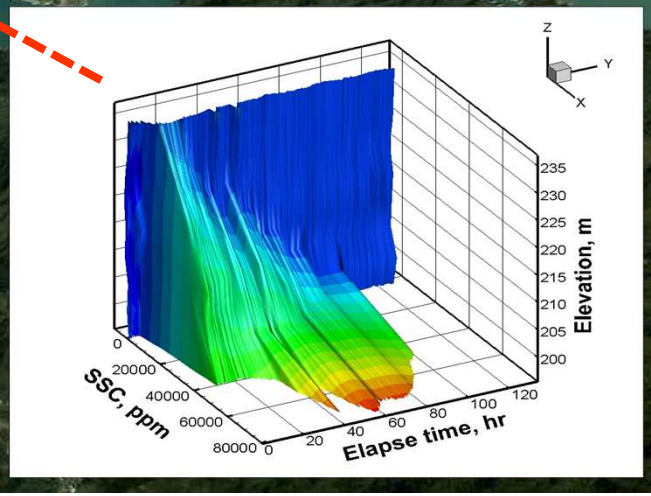


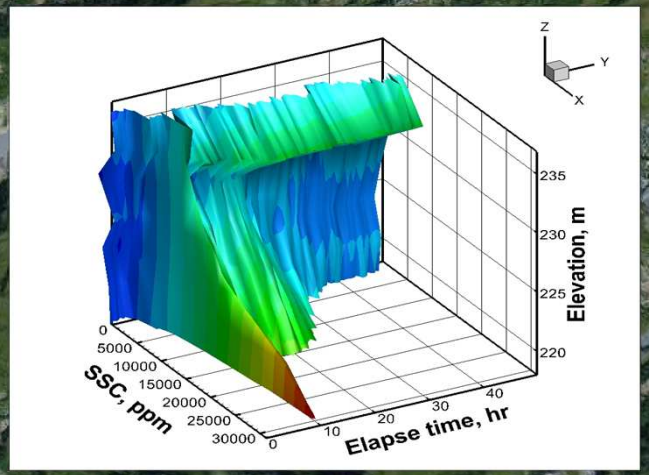
SSC monitoring during 2013 Typhoon Soulik

Peak Inflow 5458cms
Peak rainfall 94.2mm/hr
Q>300 cms over 47 hrs



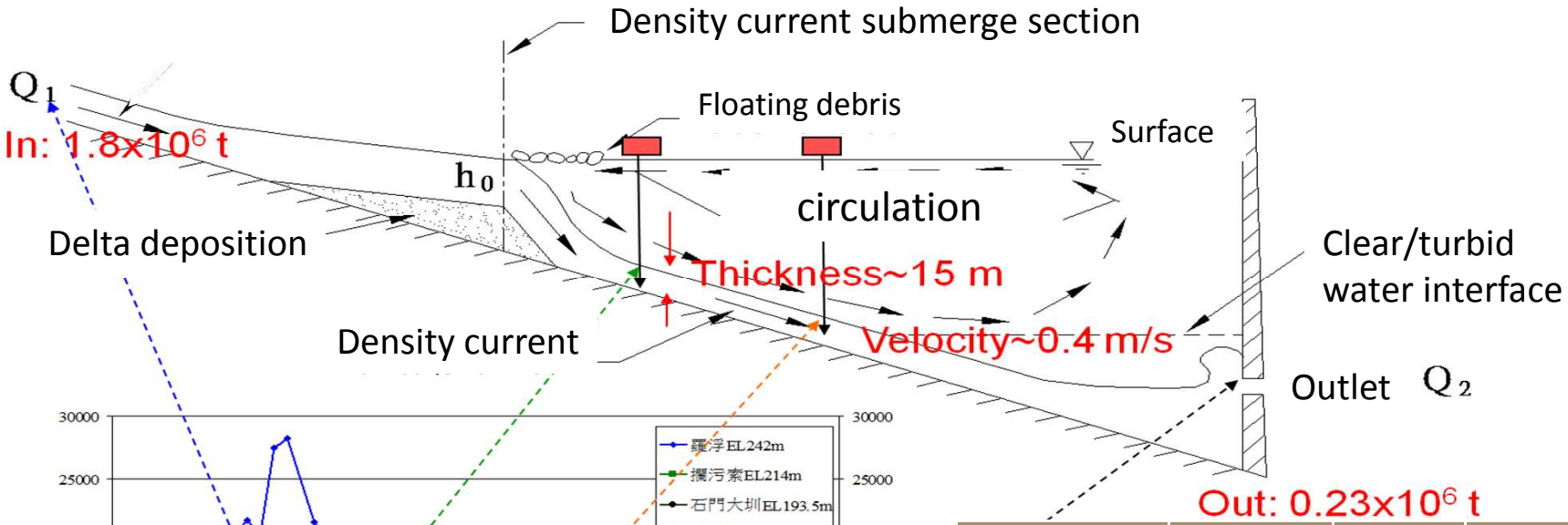


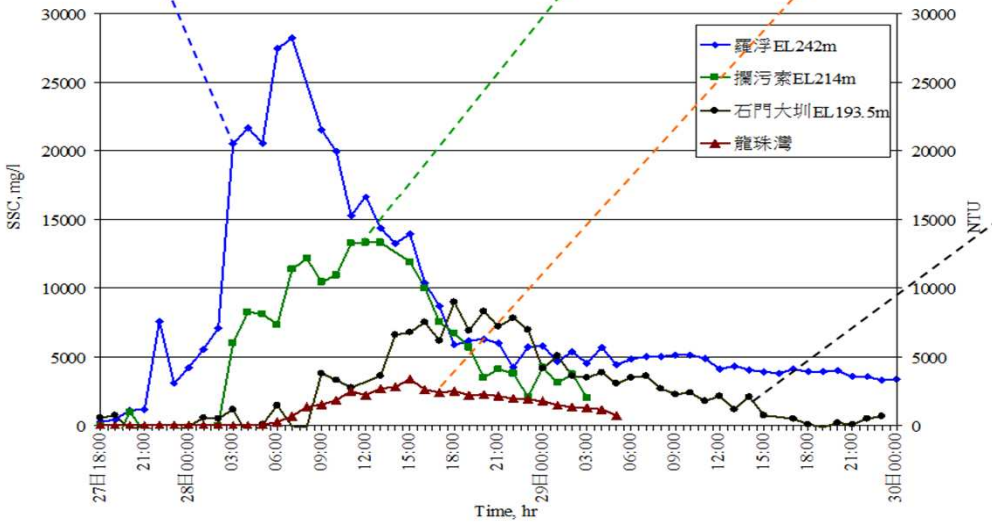




Sediment transport behaviors–Density current

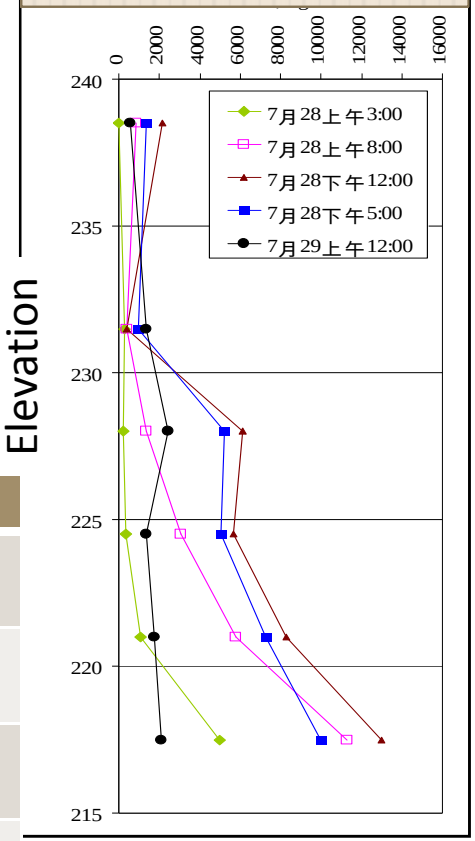
- 2008 Typhoon Fungwong



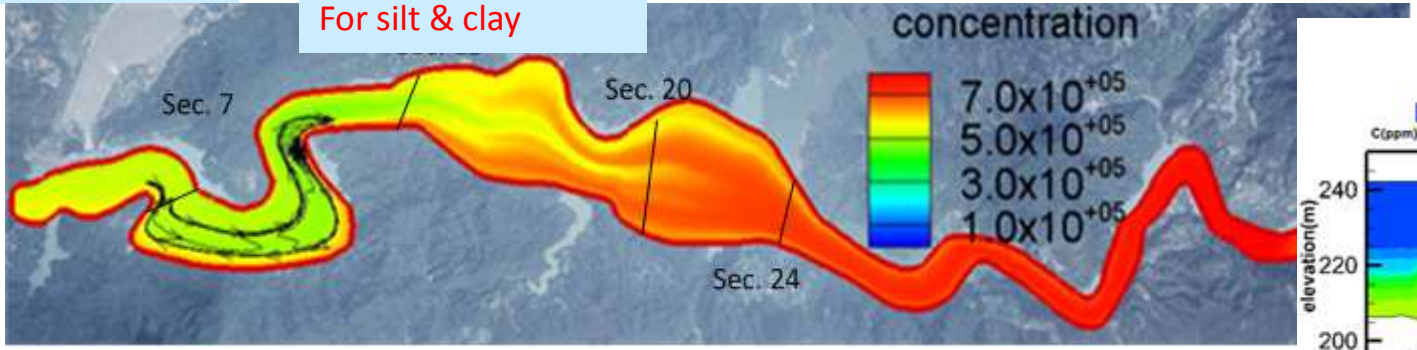


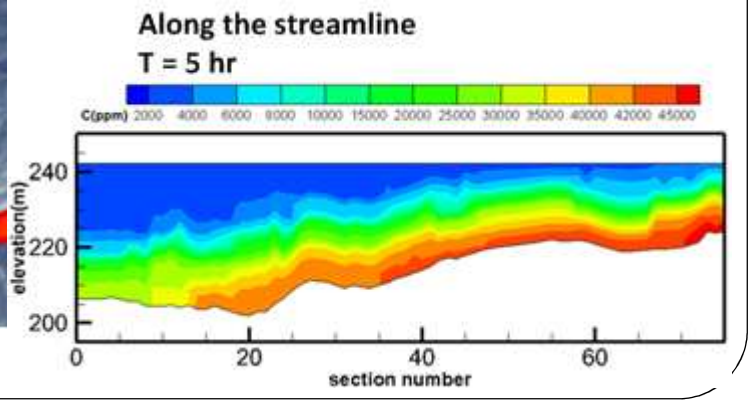
Typhoon	Fungwong	Sinlaku	Morakot
Peak discharge (cms)	2,040	3,446	1,838
Inflow volume (M m^3)	124.47	633.4	227.99
Density current velocity (m/s)	0.38	0.63	0.27
Thickness (m)	15	11.5	N/A

SSC profile wrt time at section 24



Sediment transport modeling-sediment sluice tunnel planning

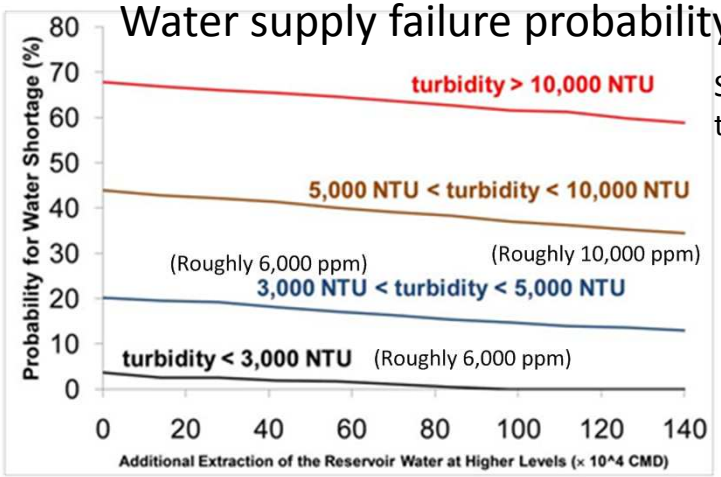




2D/3D models verified with the TDR SSC monitoring data

Sediment discharge and water intake shaft

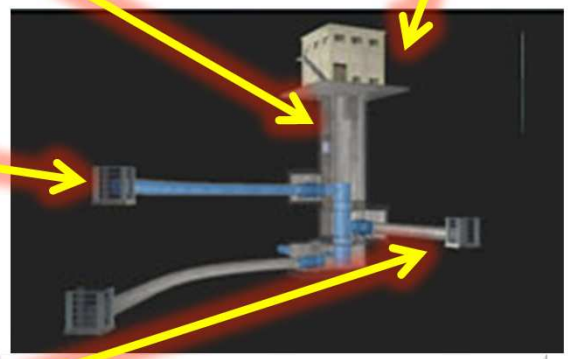
Water supply failure probability



SSC lasts less than 1 day

http://www.wra.gov.tw

Stratified water intake shaft



Sediment discharge through penstock
2013 Typhoon Soulik

Sediment sluicing and dredging for Shihmen Reservoir

Average annual sediment Inflow (10^6m^3)	Expected average annual sediment outflow (Unit: 10^6m^3)						
	PRO sluice way	Power plant penstock renovation	Dawanping silt sluice tunnel	Amuping sediment sluice tunnel	Dedging near dam	Dredging u/s from reservoir	Sum
3.42	0.15 (4%)	1.02 (30%)	0.71 (21%)	0.64 (19%)	0.50 (15%)	0.40 (12%)	3.42
	55%			19%	26%		100%

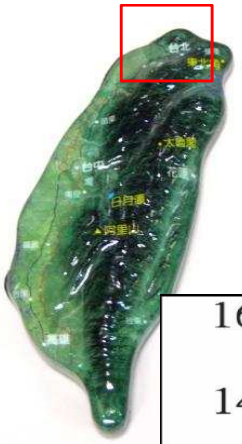
Gated sediment sluice tunnels

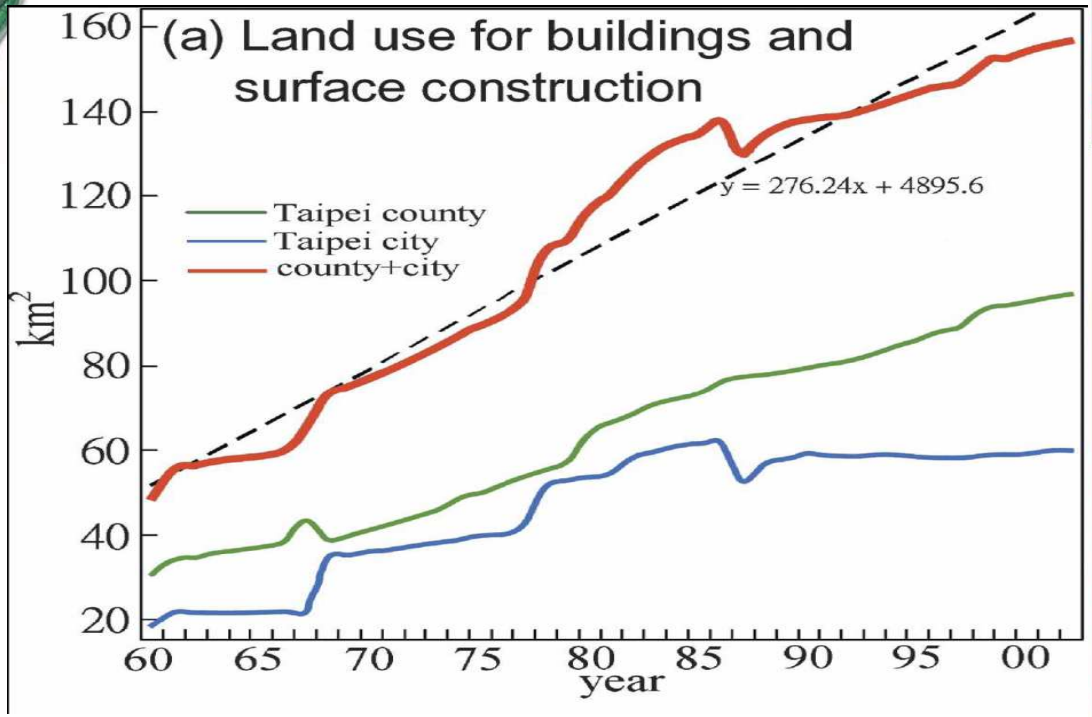
- **FEWS** may help optimal gate operation

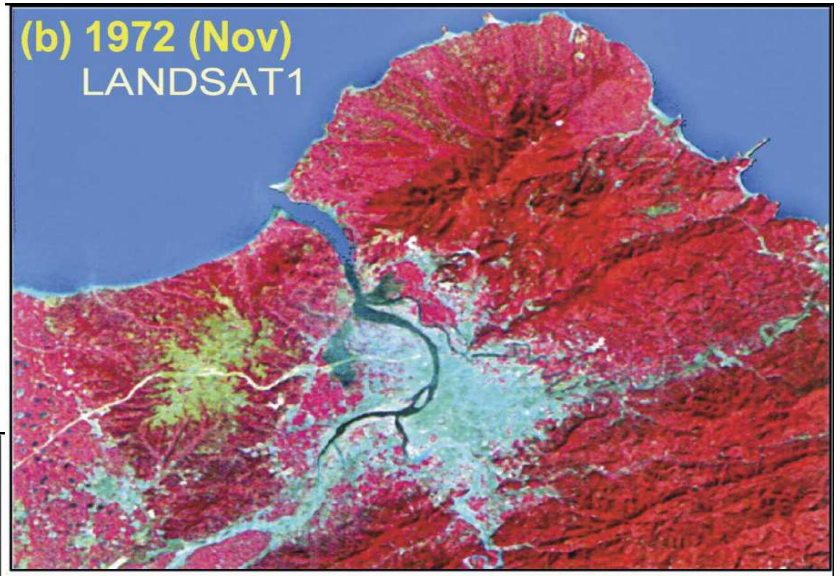
Flood management

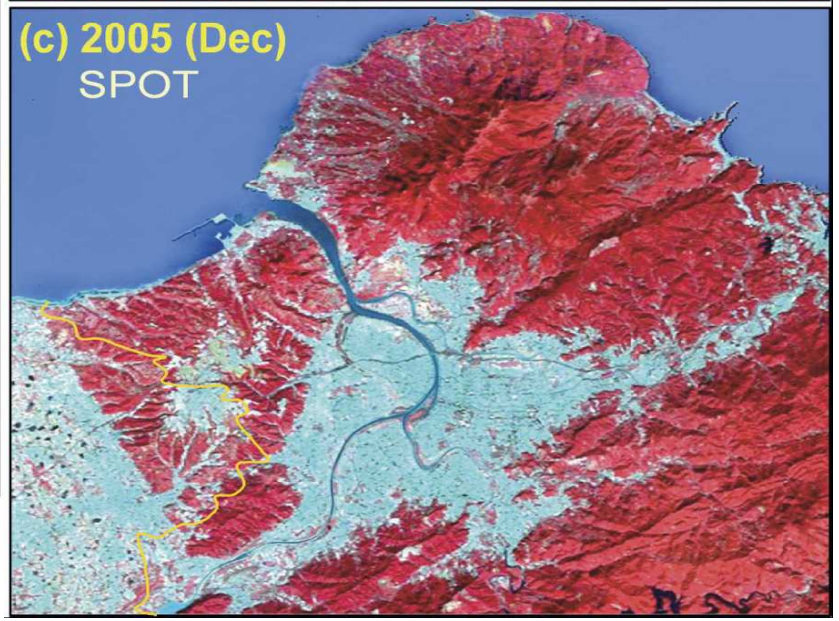
Impervious area increasing

- Land use in Taipei Basin









From: Tsing-Chang Chen et al

Flood disasters

- 171 typhoons occurred during 1958~2004
- 14,456 injured, including 2455 dead, 1098 missing
- 342,378 houses failed

Dike failure in 2004 TP Mindull

Turbid water by floods

Taipei inundation in 2001 TP Nari

Bank retreat in 2009 TP Morakot

Dike failure in 2008 TP Kalmaegi

TP Morakot after math

Coastal erosion

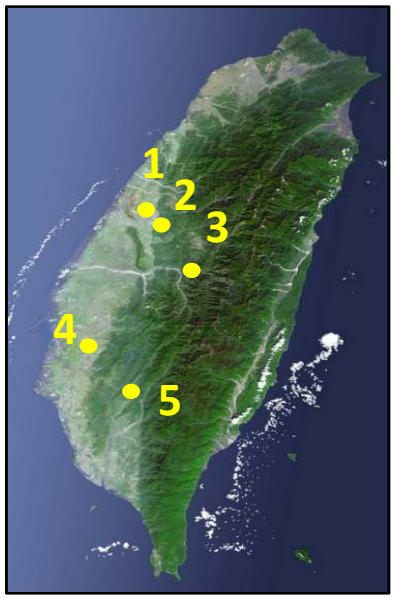
Kaohsiung inundation in 2006 TP Tanmi

Kaohsiung inundation in 2006 thunderstorm

Landslide killed 600

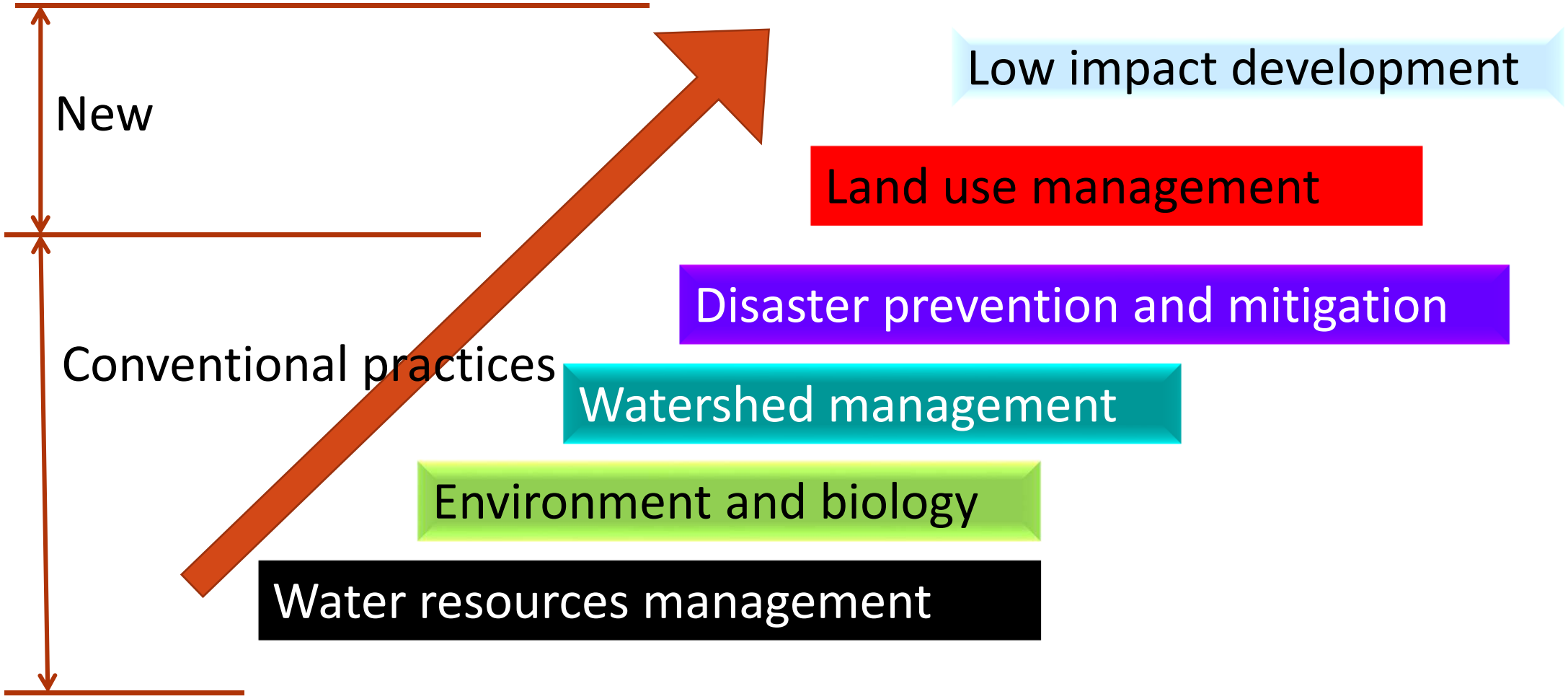
Channel erosion

- 2008 Typhoon Sinlaku damaged 5 bridges
  - Tuming Bridge
  - Hofong Bridge
  - Niouming Bridge
  - Wuhuliao Bridge
  - Chiashiang Bridge

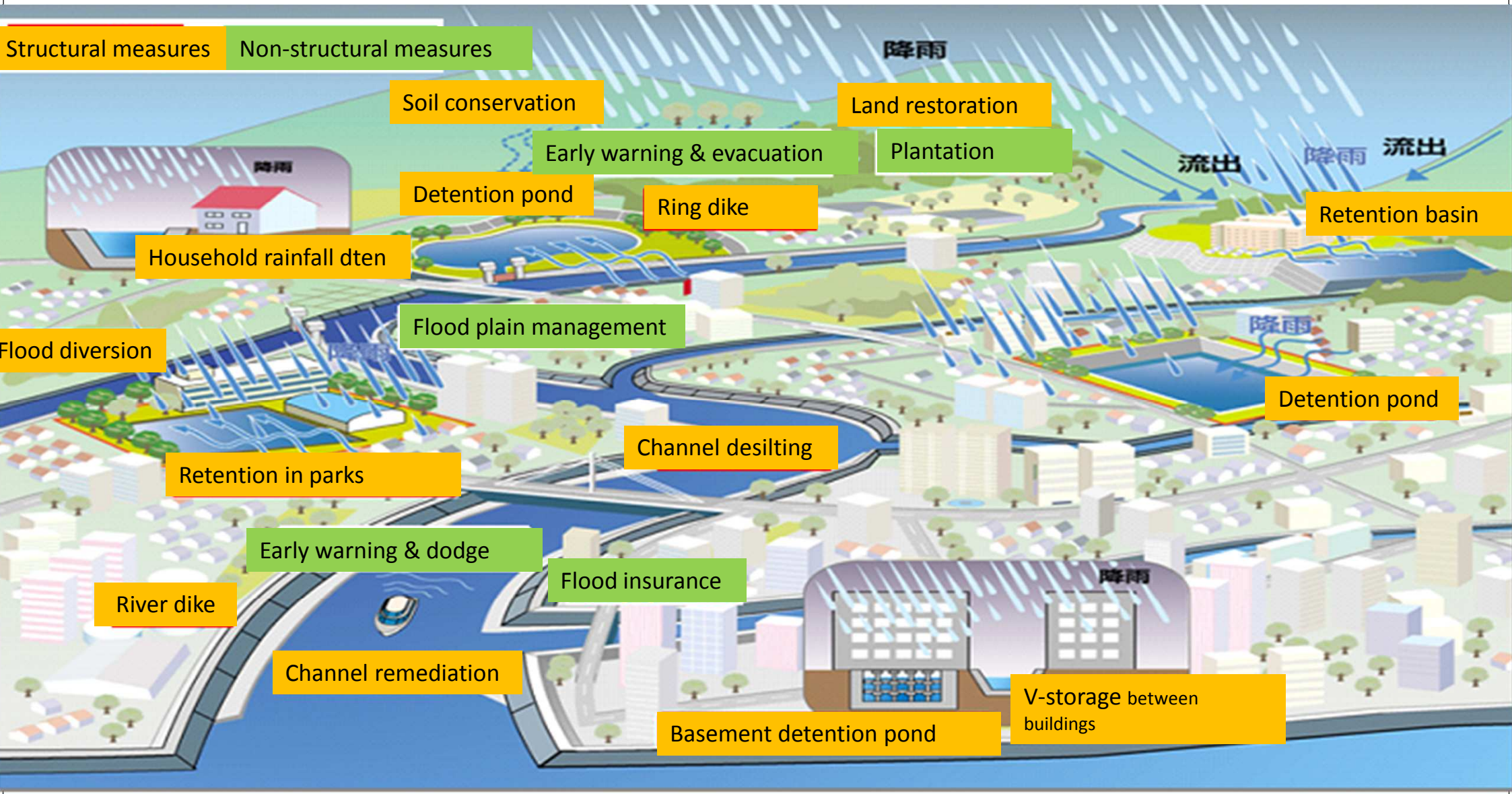


reintallation

Flood management



Ideal flood defense system

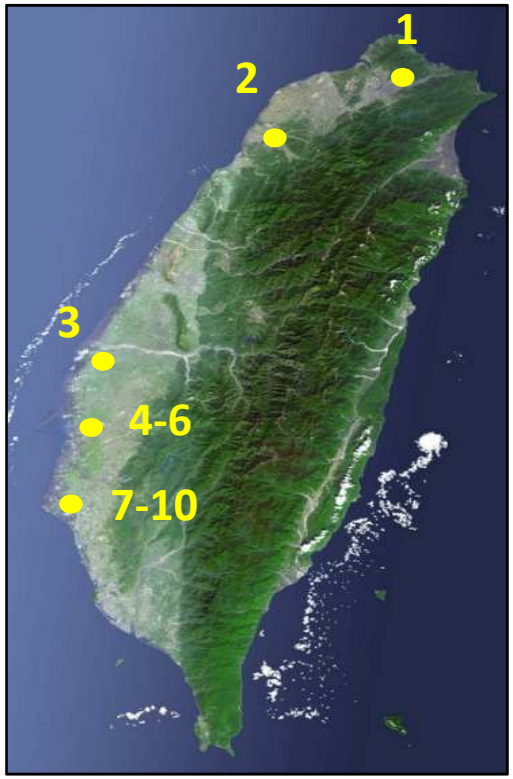


http://highscope.ch.ntu.edu.tw/

Flood detention ponds

台北大湖

楊梅高山頂



雲林南公館

嘉義白水湖A1

嘉義四股

嘉義內田考試潭

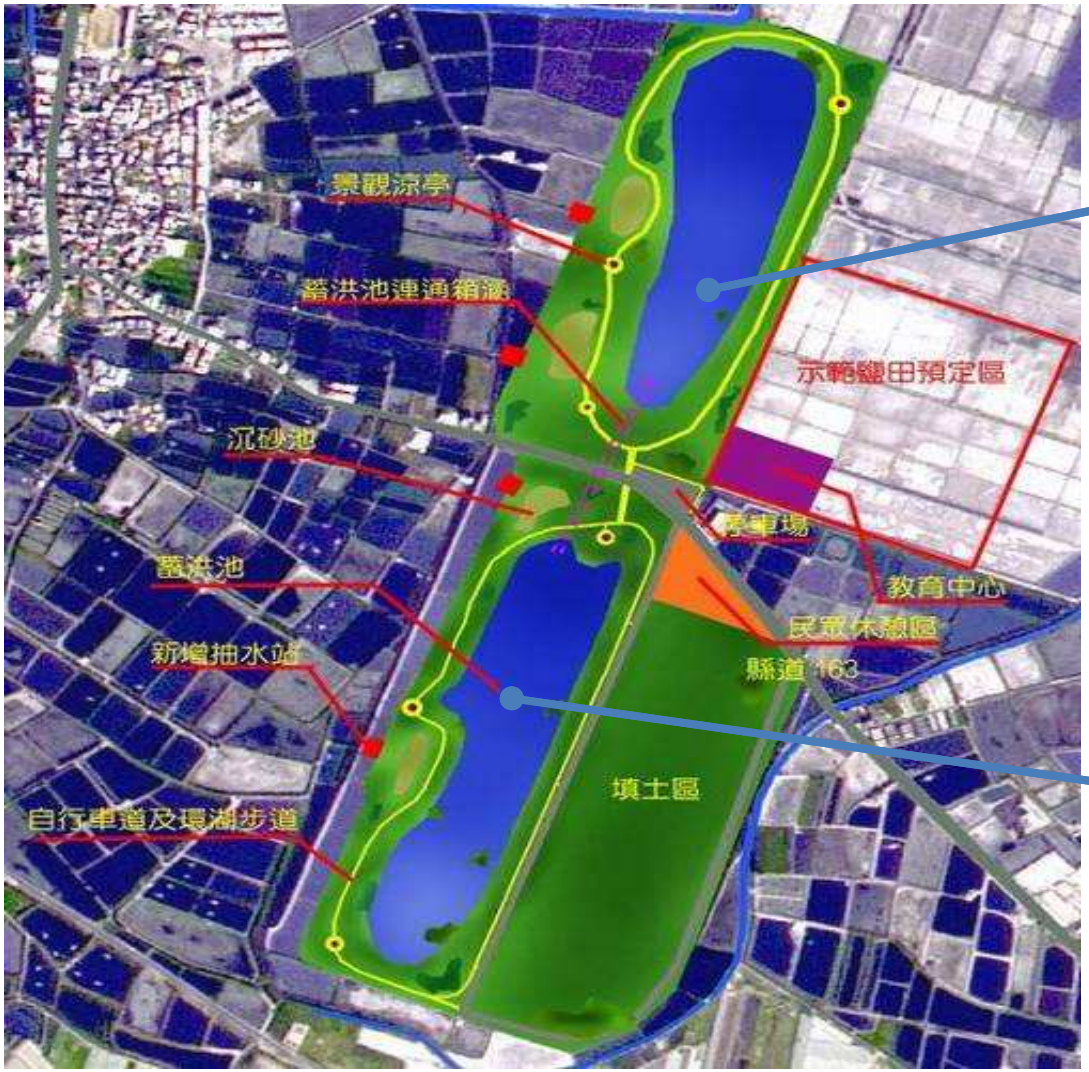
台南立德

南科D池

台南三舍

台南都會公園

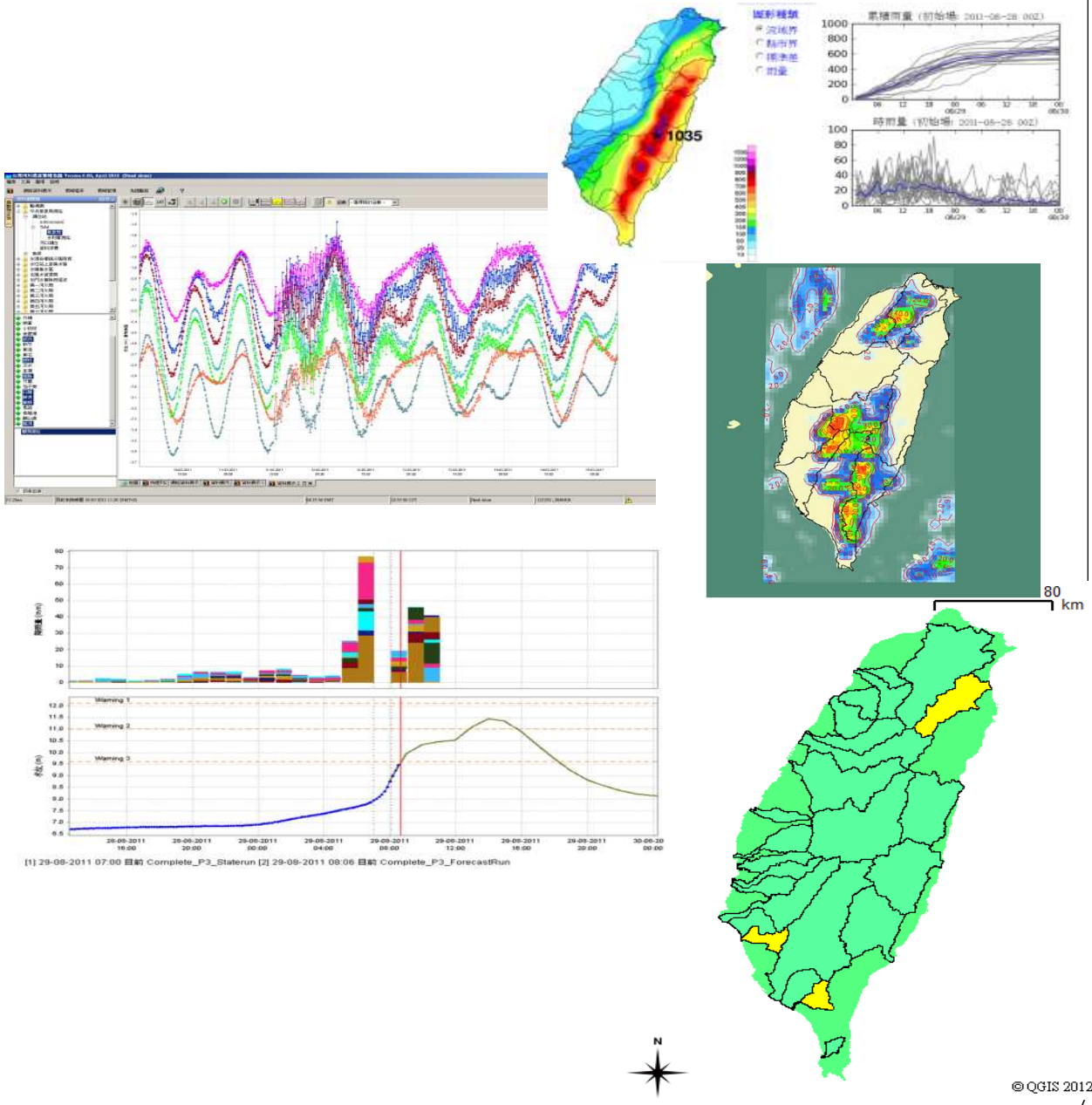
Detention ponds for protecting high value fish farms



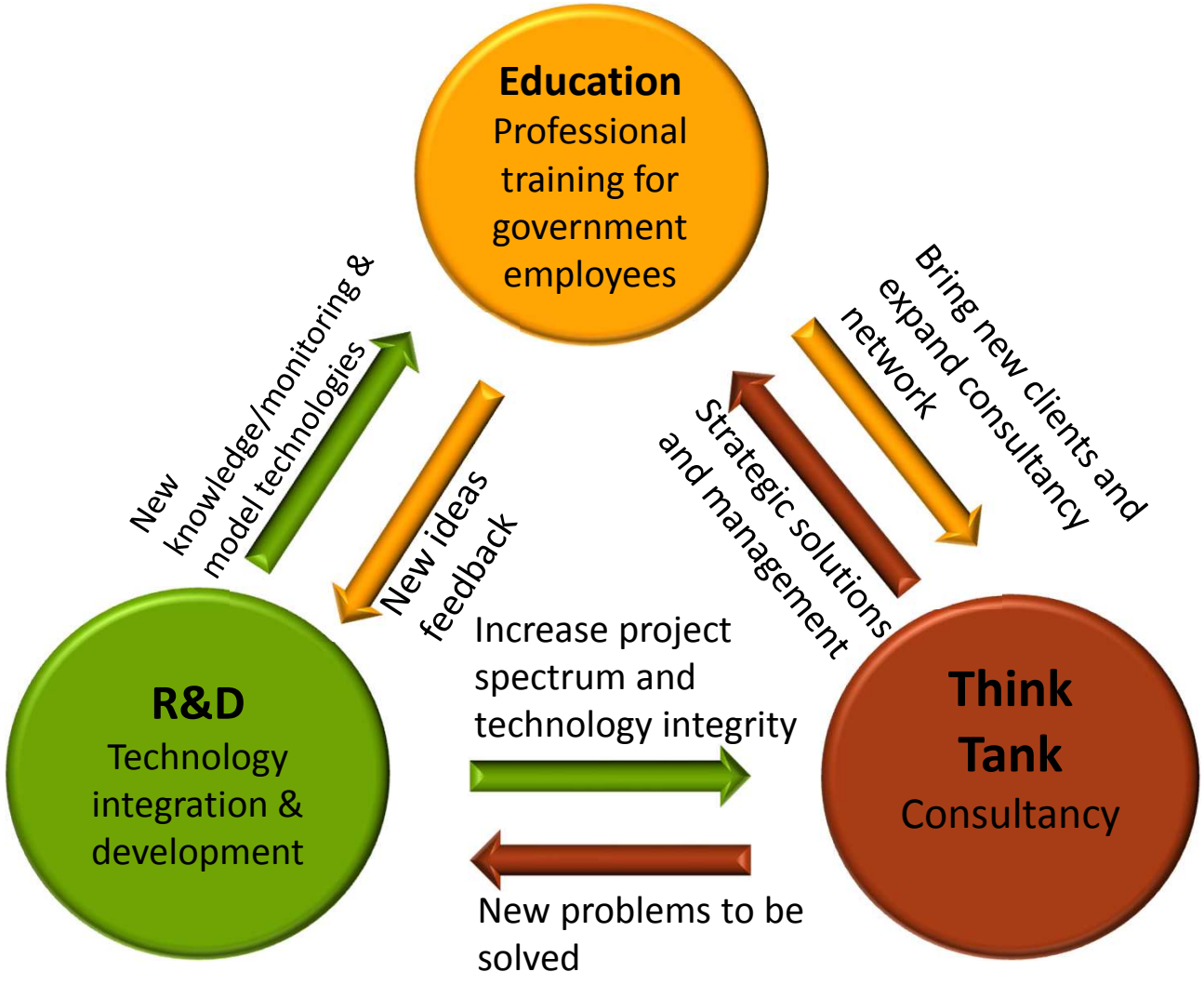
Collaboration with Deltares

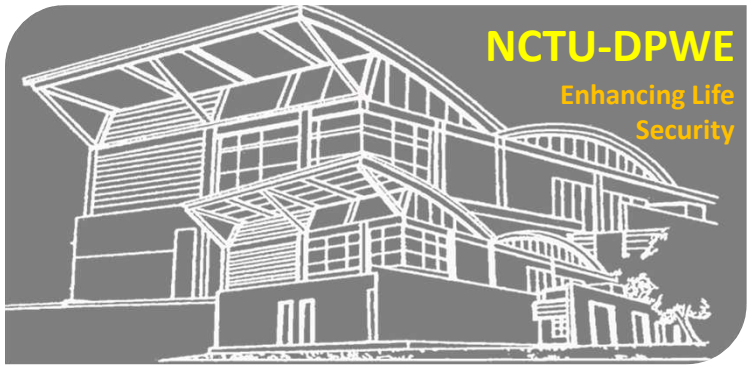
FEWS_Taiwan

- River basins
  - 26 rivers ready
- Models
  - SOBEK
  - HEC-RAS
  - WRF Ensemble
  - Real-time water level correction
- System
  - FEWS_Taiwan Live System
- Collaboration groups
  - Deltares, WRA, NCTU
- Model integration into FEWS
  - Landslide model
  - Reservoir operation model
  - River bank retreat model



Look forward to future collaboration





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Deltares
Enabling Delta Life

Thanks for your patience

Comments?

Visit NCTU-DPWE at http://dpwe.nctu.edu.tw/en/

Enhance joint security by joining force with Deltares

- **Real-time monitoring and modeling in**
  - Sediment transport → Clean water supply & life expectancy of reservoir
  - River dike safety → Life security near river bank
  - Landslide forecasting → Life security near/on slopes
  - River structure safety → Life security near hydro-infrastructure
- **Long term planning**
  - Landsubsidence modeling and monitoring → subsidence prevention planning
  - Inundation mapping → Levee design and inundation prevention
  - Groundwater resources management → Ind. & agr. development
  - Safe drinking water → Clean water supply