WRA 經濟部水利署

2012 R&D FORUM

國立臺灣大學 氣候天氣災害研究中心
Center for Weather Climate and Disaster Research

The Climate Change of Flood and Debris Mitigation after Typhoon Morakot 2009 in Taiwan

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Outline

1. Overview
2. The scenarios of hydrological conditions
3. The Impact Assessment of Flood Prevention System of Kaopig River
4. Preliminary Vulnerability and Risk Evaluation
5. Action plan
6. Conclusions

1.Overview

Objective

Origin

Climate change has brought huge impacts to the whole world. Those impacts include:

- Severe floods
- Spatial land change
- change of hydrological conditions
- etc..

Flood-prevention works needs to be re-evaluated

Kaoping weir
高屏溪攔河堰

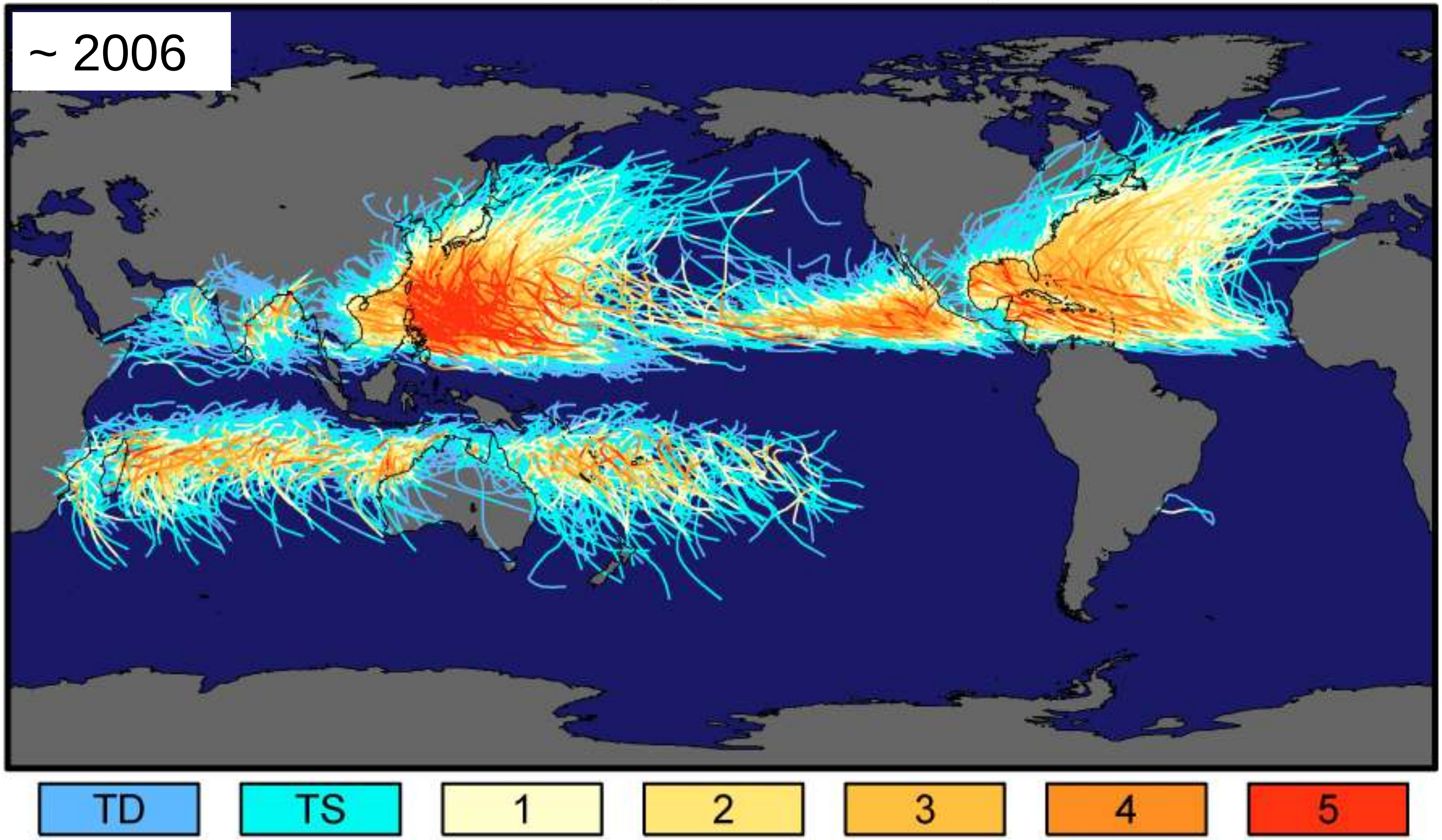
Shuangyuan Bridge
(雙園大橋)

Objective

- Evaluate impacts of flood-prevention works of Kaoping River due to climate change
- Risk evaluation of flood-prevention works
- Strategies and action plans for improving adaptation capacity of flood-prevention works due to climate change

Study Area-Kaoping River

全球颱風分布狀況

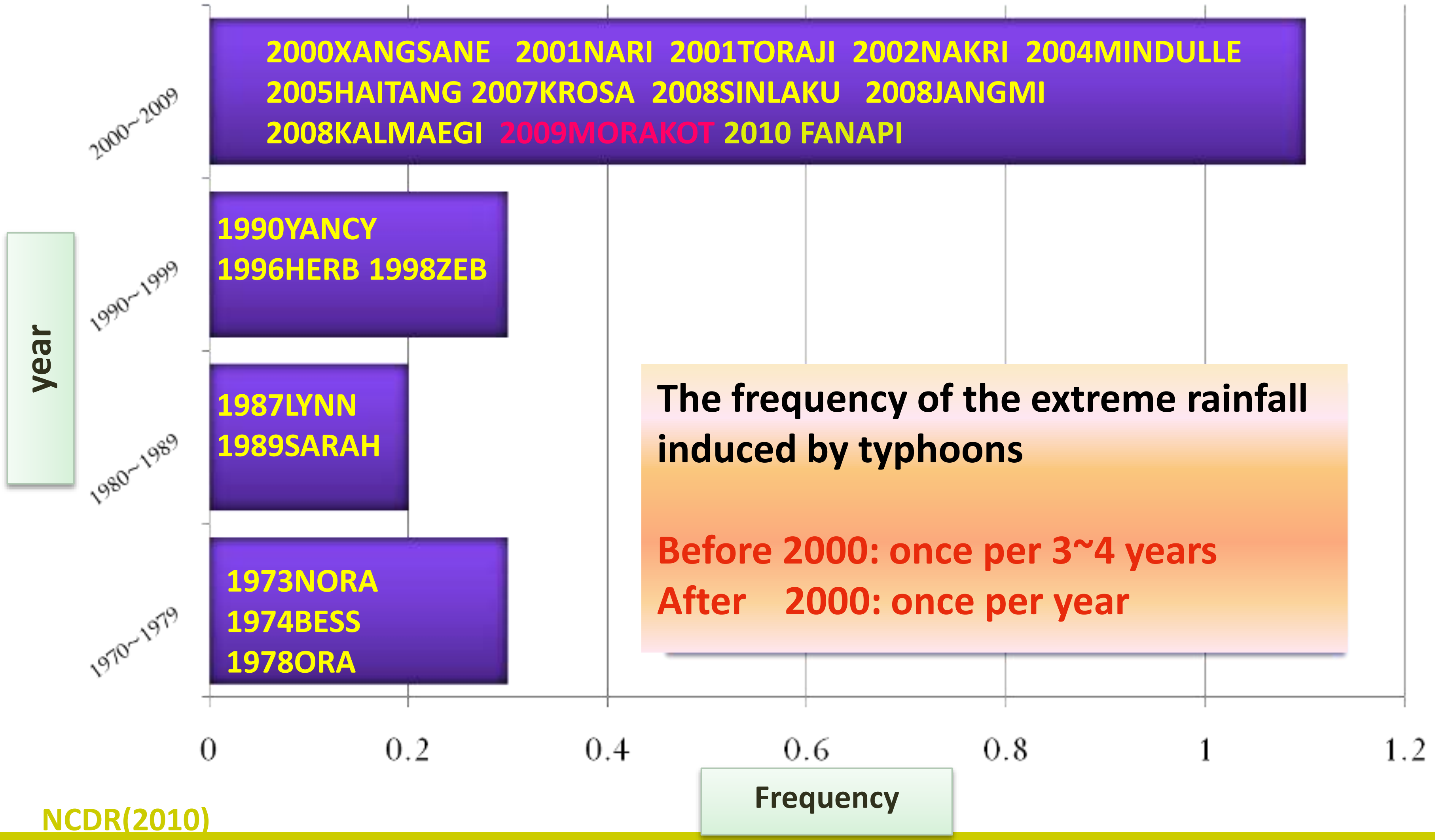


Tracks and Intensity of All Tropical Storms

~ 2006

Saffir-Simpson Hurricane Intensity Scale

Frequency of the extreme rainfall induced by typhoons (the top 20 of the rainfall index between 1970 and 2009)

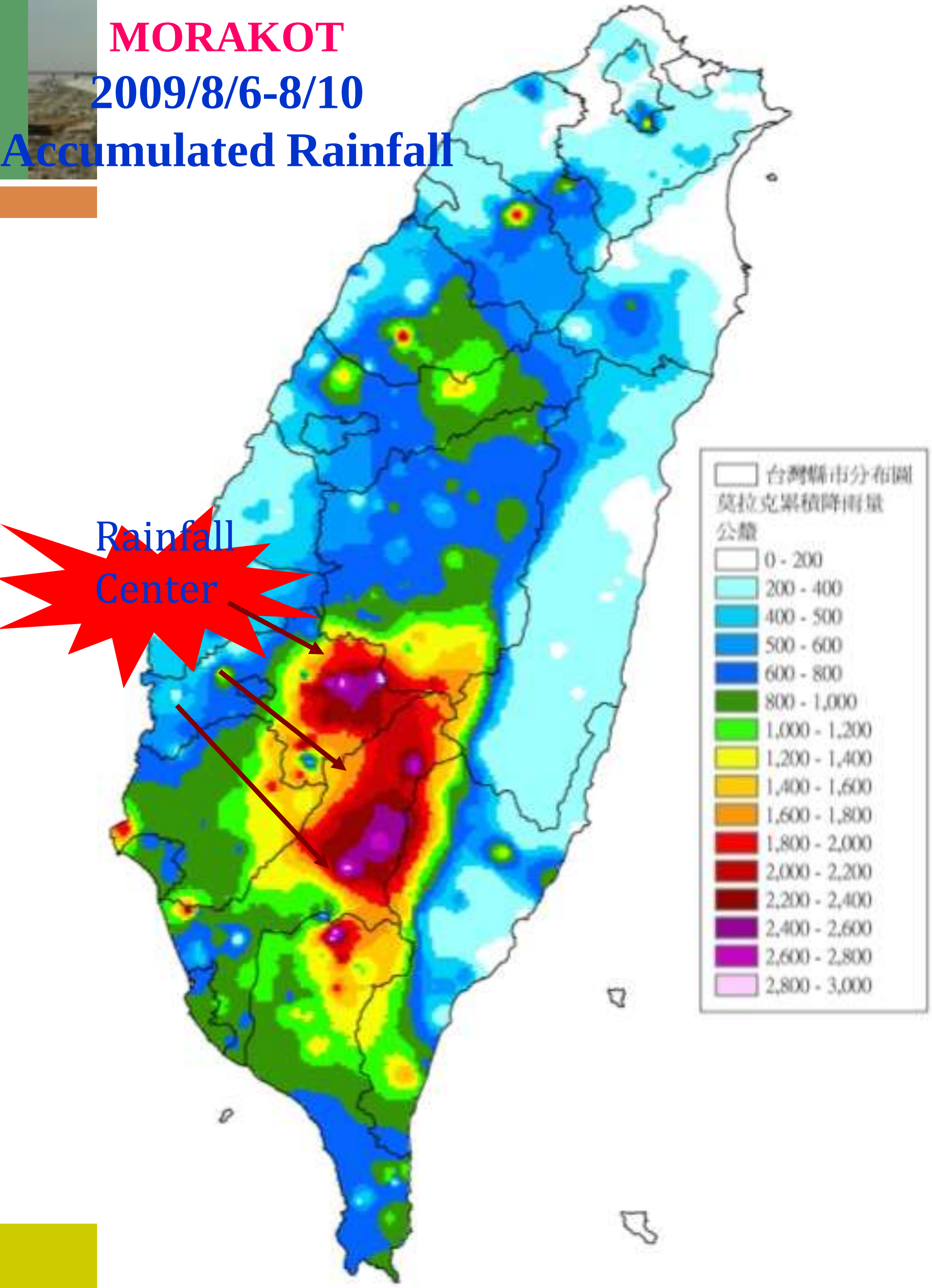


The frequency of the extreme rainfall induced by typhoons

Before 2000: once per 3~4 years
After 2000: once per year

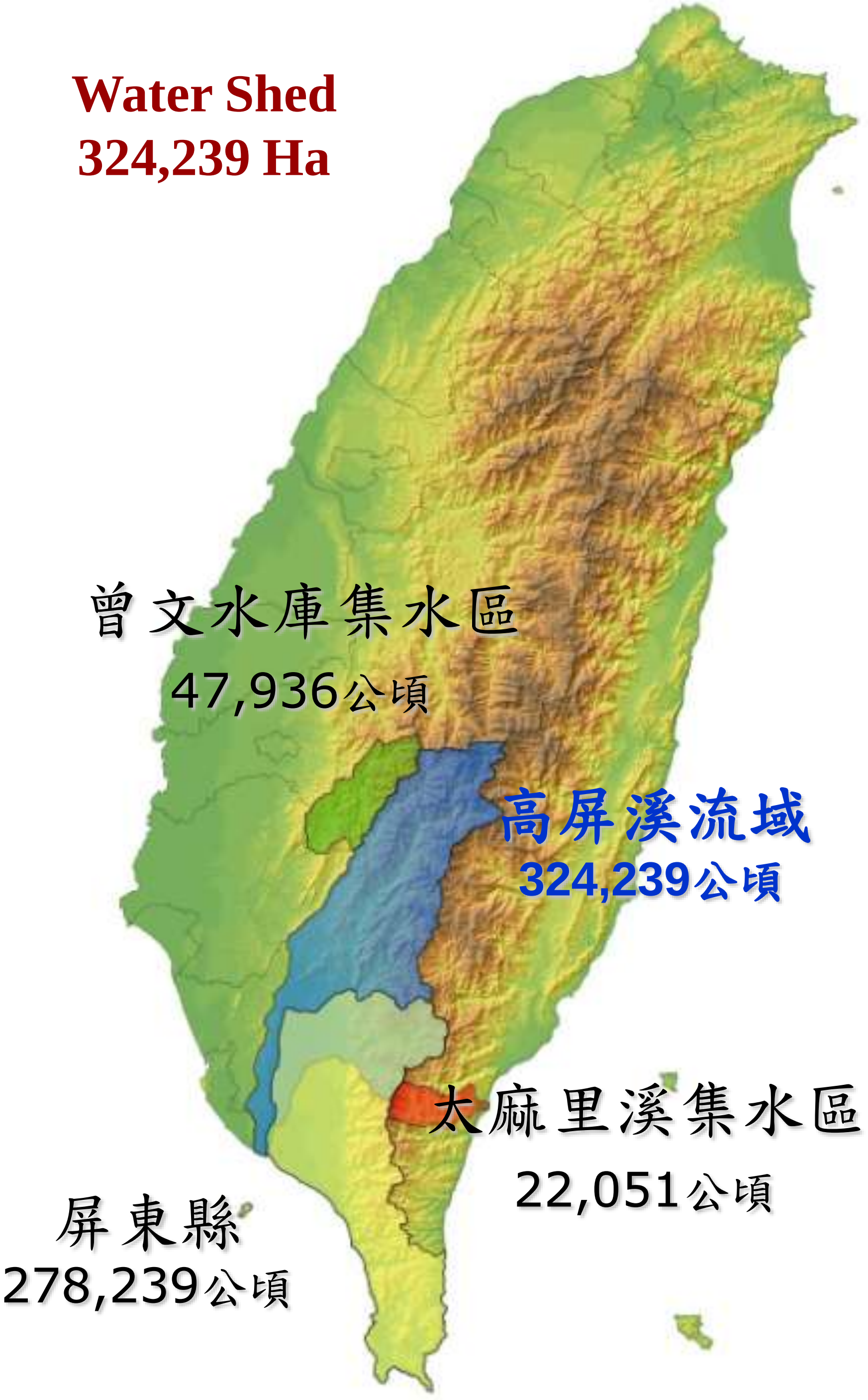
NCDR(2010)

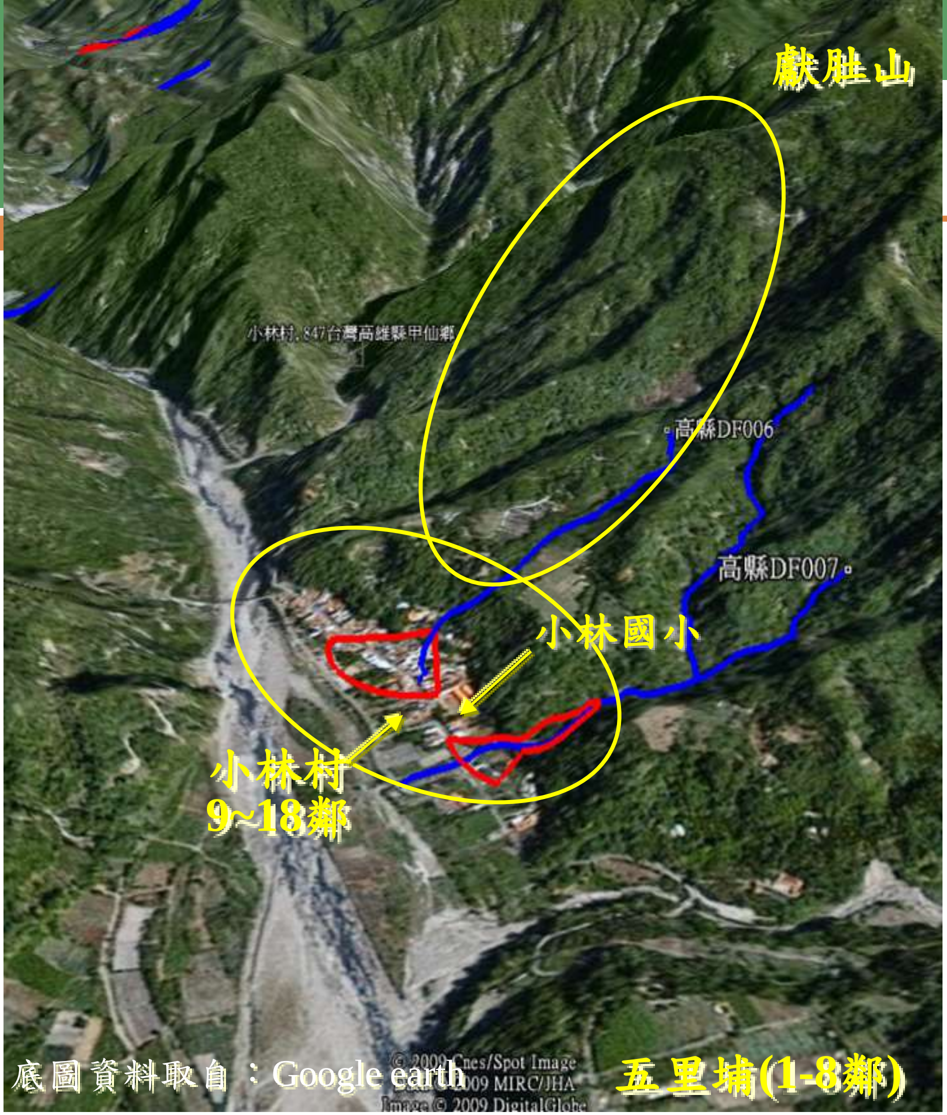
MORAKOT
2009/8/6-8/10
Accumulated Rainfall



Rainfall Center

Water Shed
324,239 Ha



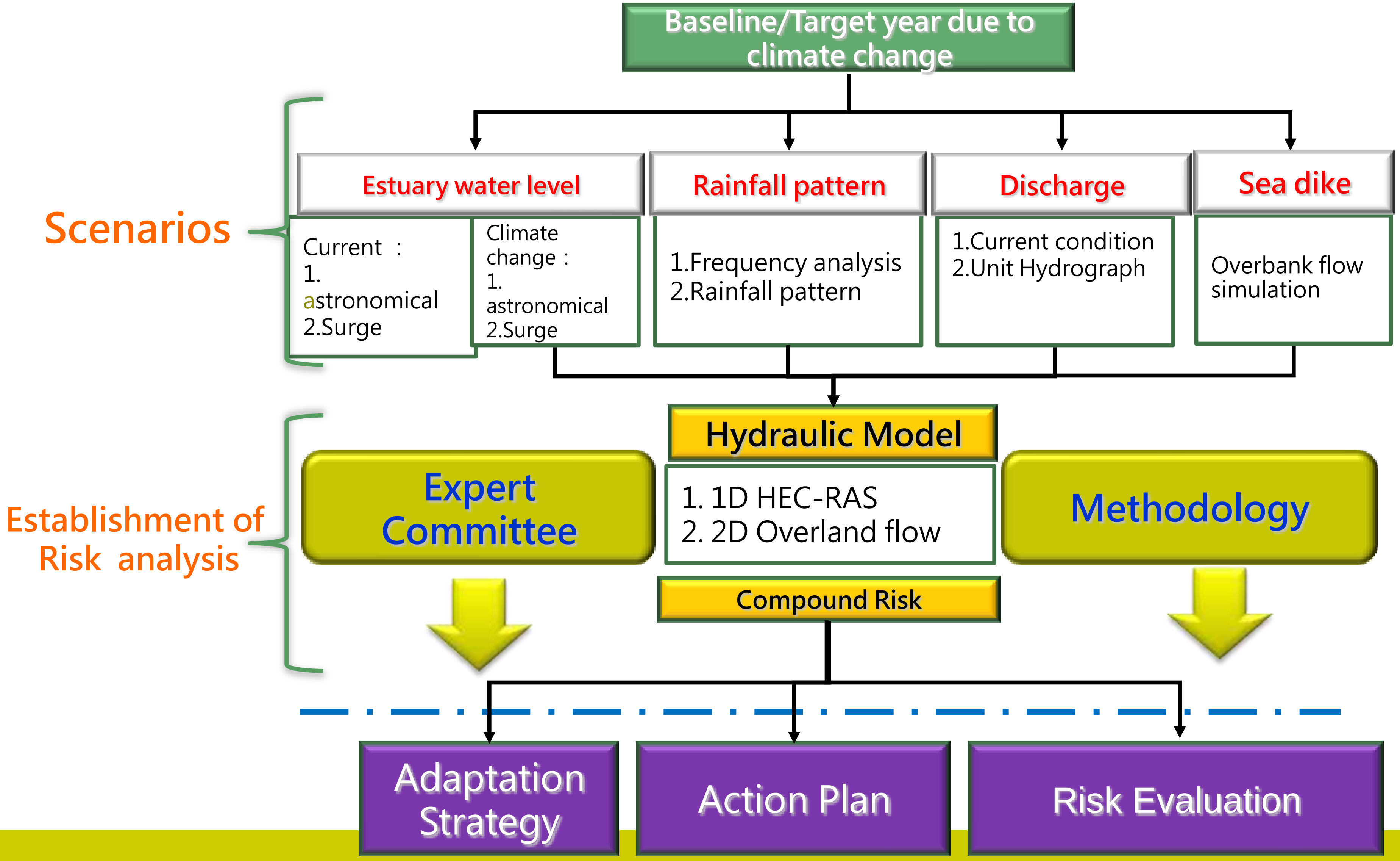


底圖資料取自：Google earth

- ✓ 原植被良好(左圖)，藍色線條為土石流潛勢溪流，紅色線條為土石流影響範圍，概估土砂量8萬方，疏散地點為小林國小。
- ✓ 崩塌地點(右圖)為獻肚山走山崩塌，崩塌土砂量950萬方，掩埋小林村9~18鄰。

水保局
2009

Work flowchart



Baseline/Target year due to climate change

Scenarios

Estuary water level

Current :
1. astronomical
2.Surge

Climate change :
1. astronomical
2.Surge

Rainfall pattern

1.Frequency analysis
2.Rainfall pattern

Discharge

1.Current condition
2.Unit Hydrograph

Sea dike

Overbank flow simulation

Establishment of Risk analysis

Expert Committee

Hydraulic Model

1. 1D HEC-RAS
2. 2D Overland flow

Methodology

Compound Risk

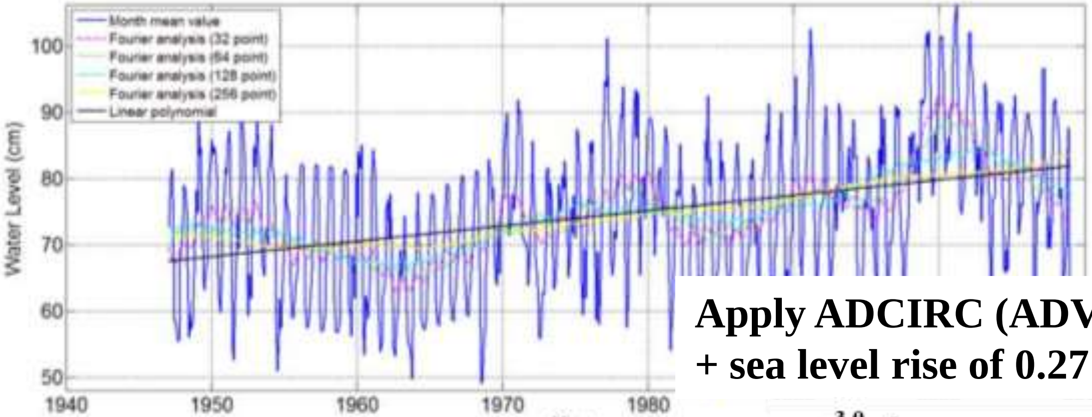
Adaptation Strategy

Action Plan

Risk Evaluation

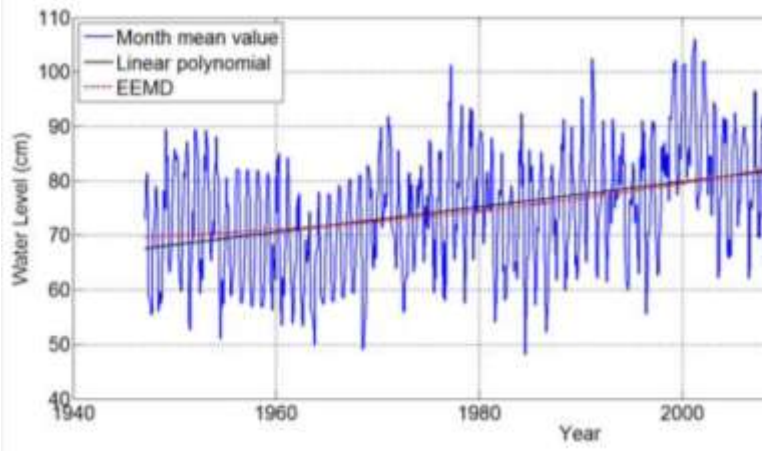
2. The scenarios of hydrological conditions

Scenarios of hydrological conditions -Sea Level Rise of Estuary



The estimated increased sea level rise of south-eastern coast of Taiwan is 18-27 cm in 2039.

Apply ADCIRC (ADVANCED CIRCULATION MODEL) model + sea level rise of 0.27 m.

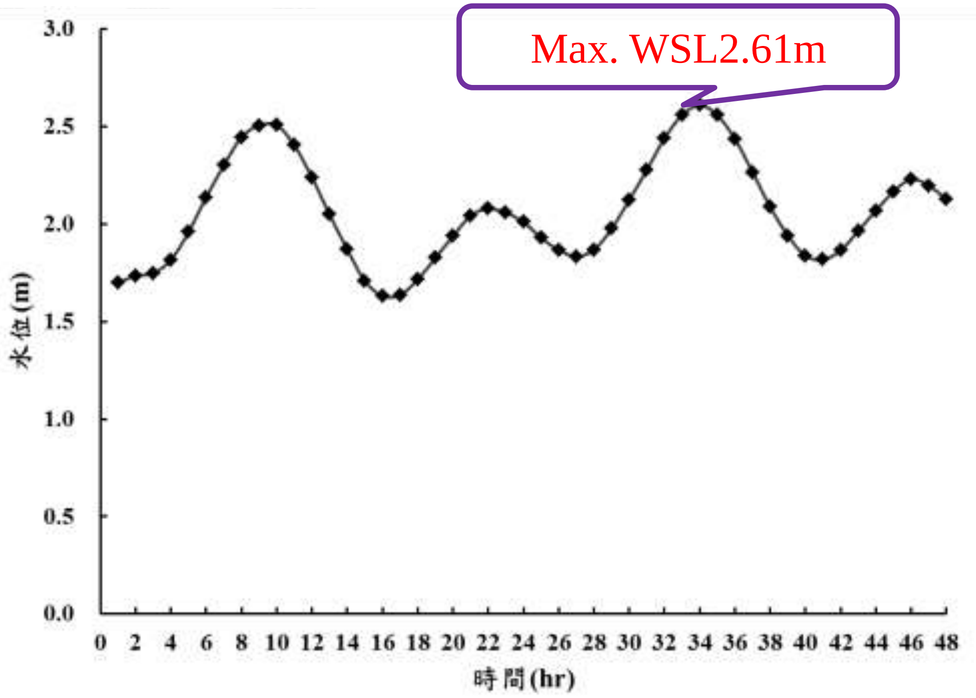


(資料來源: 強化台灣西南地區因應氣候變遷海岸災害調適

Historical tidal data for 1947 to 200

(a) Fast Fourier Transform and regr

(b) EEMD and projected for 2039



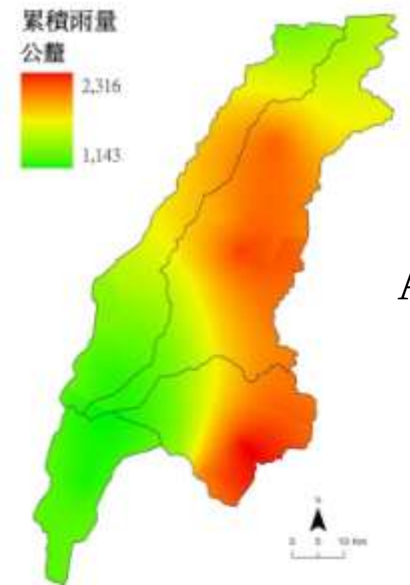
48hr-Water surface level of estuary of Kaoping River due to climate change

Rainfall for different scenarios

48hr-Rainfall-Return period:100yr (2020-2039)

Cumulative Rainfall (mm)

Station **Scenario**	Jiasian(2) [甲仙(2)]	Pingtung(5) 屏東(5)	Xinfeng(新豐)	Yushan(玉山)
A1B	1371.98	1143.43	1163.52	569.72
A2	1457.30	1205.66	1197.79	644.11
B1	1466.05	1153.16	1154.14	590.61



A1B

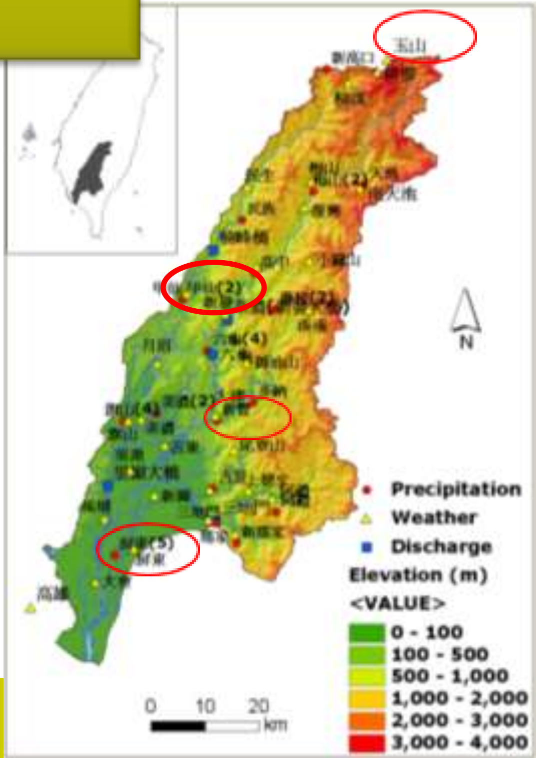
Pointed Rainfall to Areal Rainfall

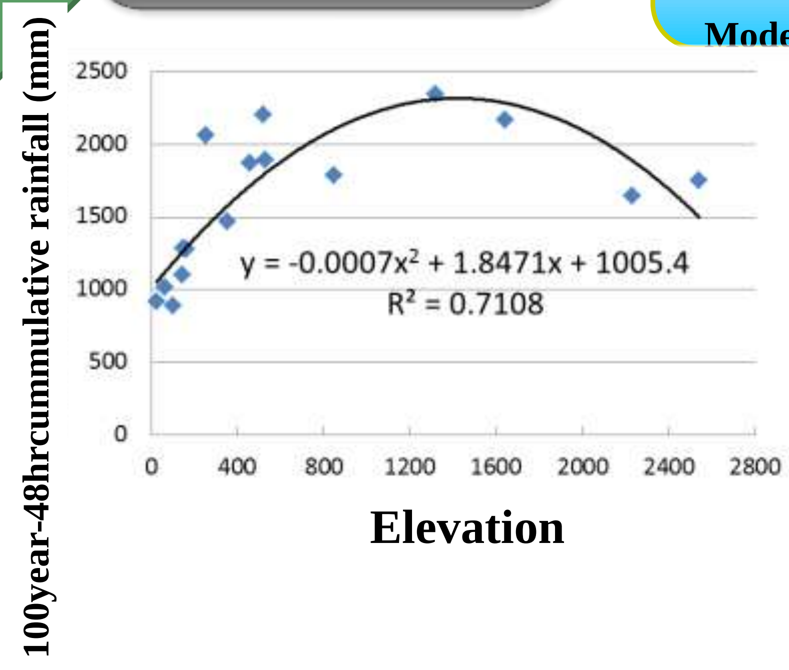
Rainfall data of GCM:
Yushan (玉山), Xinfeng (新豐), Jiasian (2)(甲仙(2)), and Pingtung(5) (屏東(5))

- 48-hr cumulative rainfall vs. elevation
- Thiseen method for weighting.

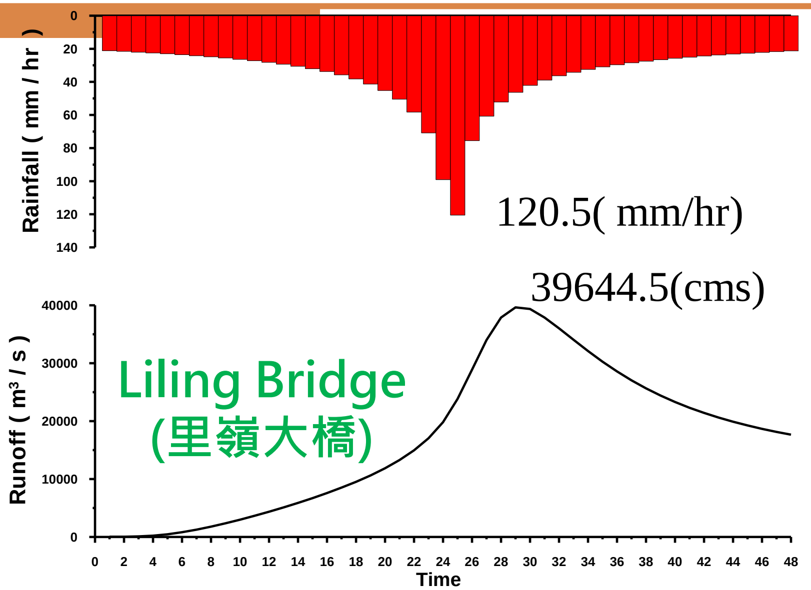
Rainfall Distribution

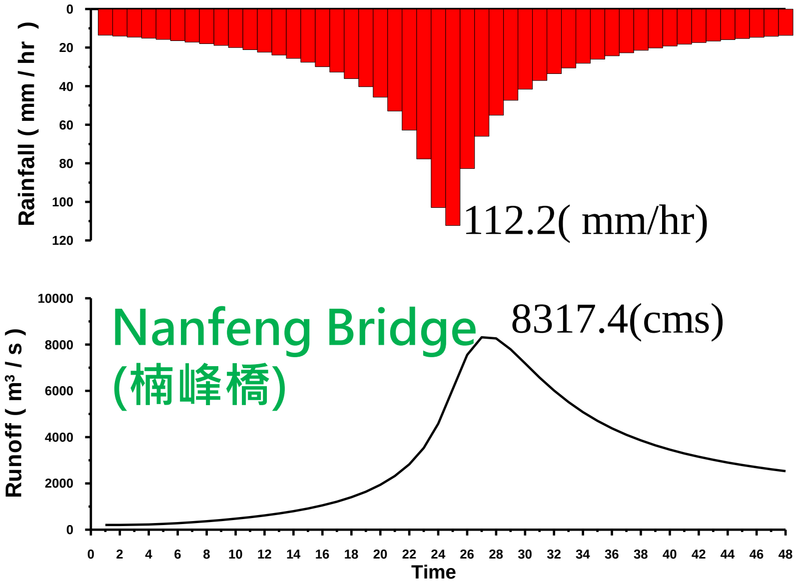
- Rainfall-Runoff Model
- Overland flow
- Sediment Model

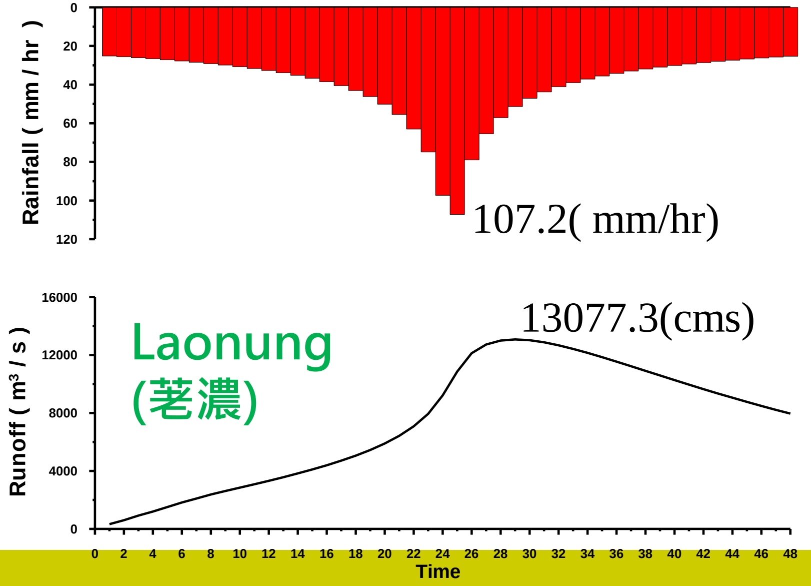


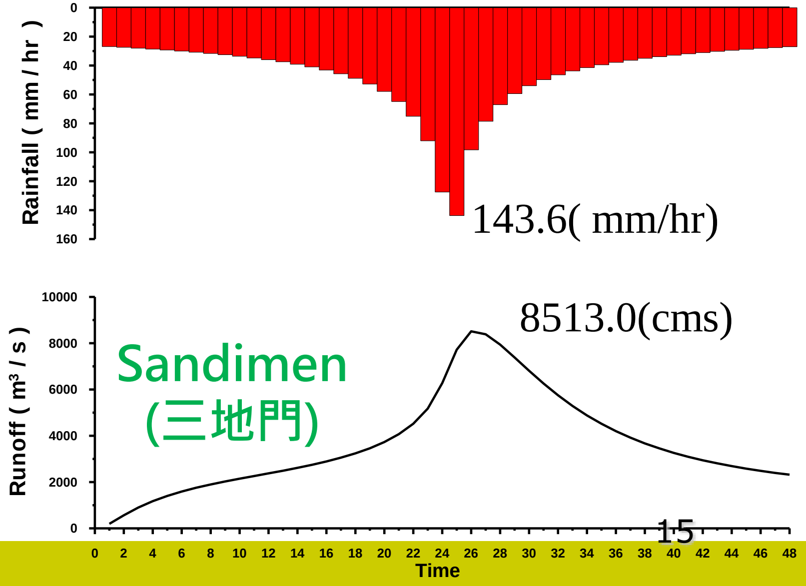


Discharge due to Climate Change



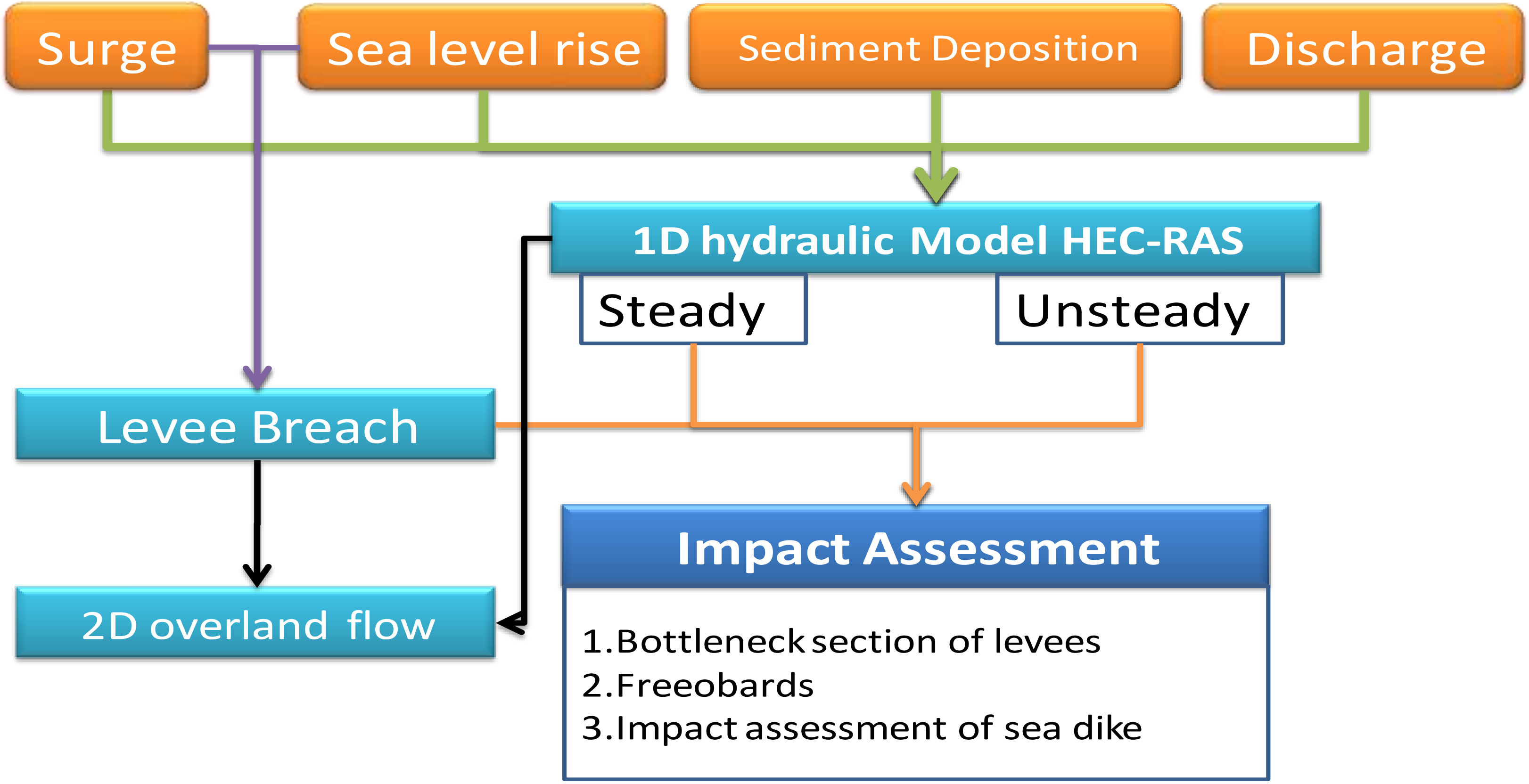






3.The Impact Assessment of flood-prevention works

Flow Chart Evaluations of Flood-Protection works



Surge

Sea level rise

Sediment Deposition

Discharge

1D hydraulic Model HEC-RAS

Steady

Unsteady

Levee Breach

2D overland flow

Impact Assessment

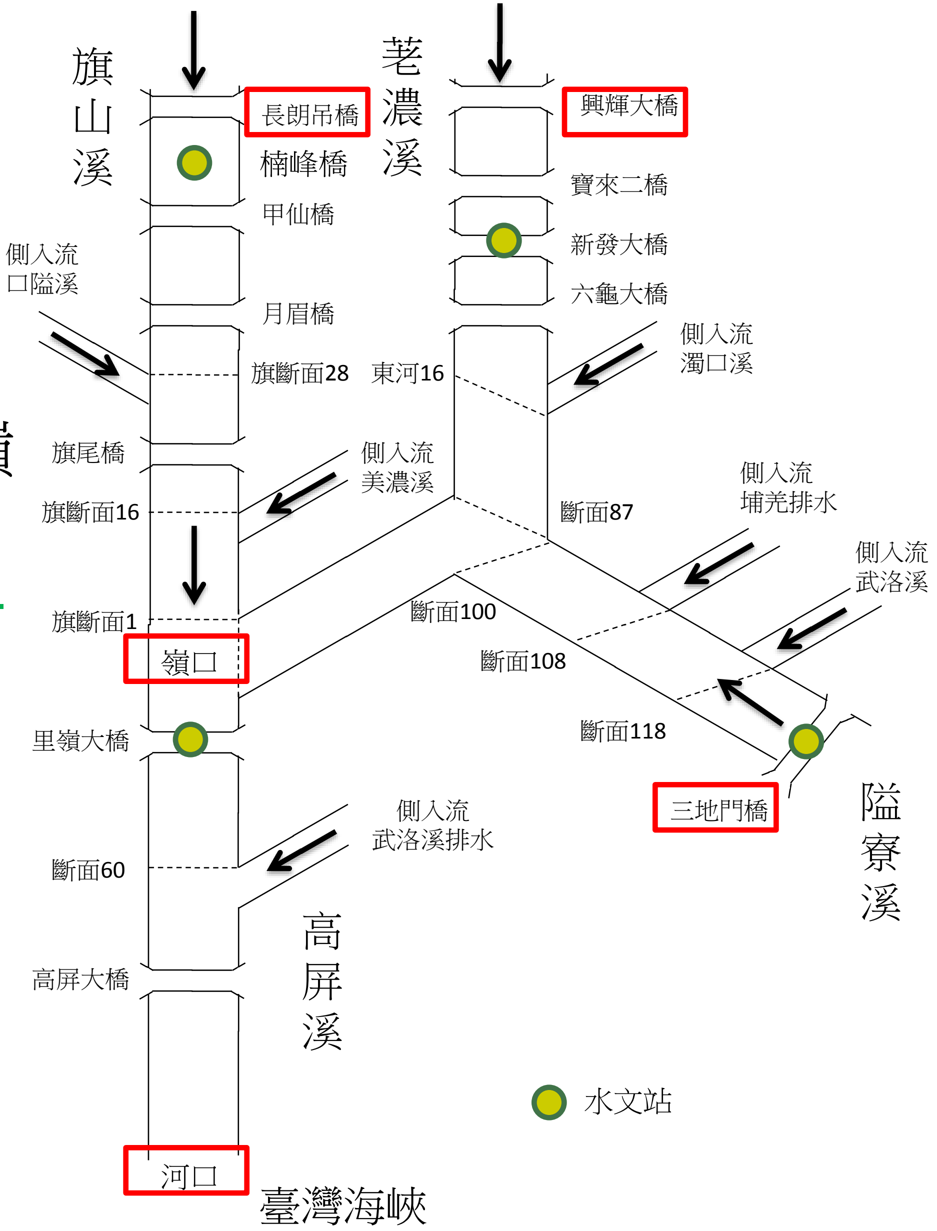
1.Bottleneck section of levees
2.Freeobards
3.Impact assessment of sea dike

Study Area

Kaoping River, Qishan River(旗山溪),Laonnog River(茗濃溪), and Ailiao River(隘寮溪).

- Kaoping River Mouth-lingkou(嶺口)。
- Laonnog River：Lingkou(嶺口)-Henfield Bridge(興輝大橋)
- Qishan River:Lingkou-Changlang suspension bridge(長朗吊橋)
- Ailiao River:Zaixing he-Sandimen Bridge(三地門橋).。

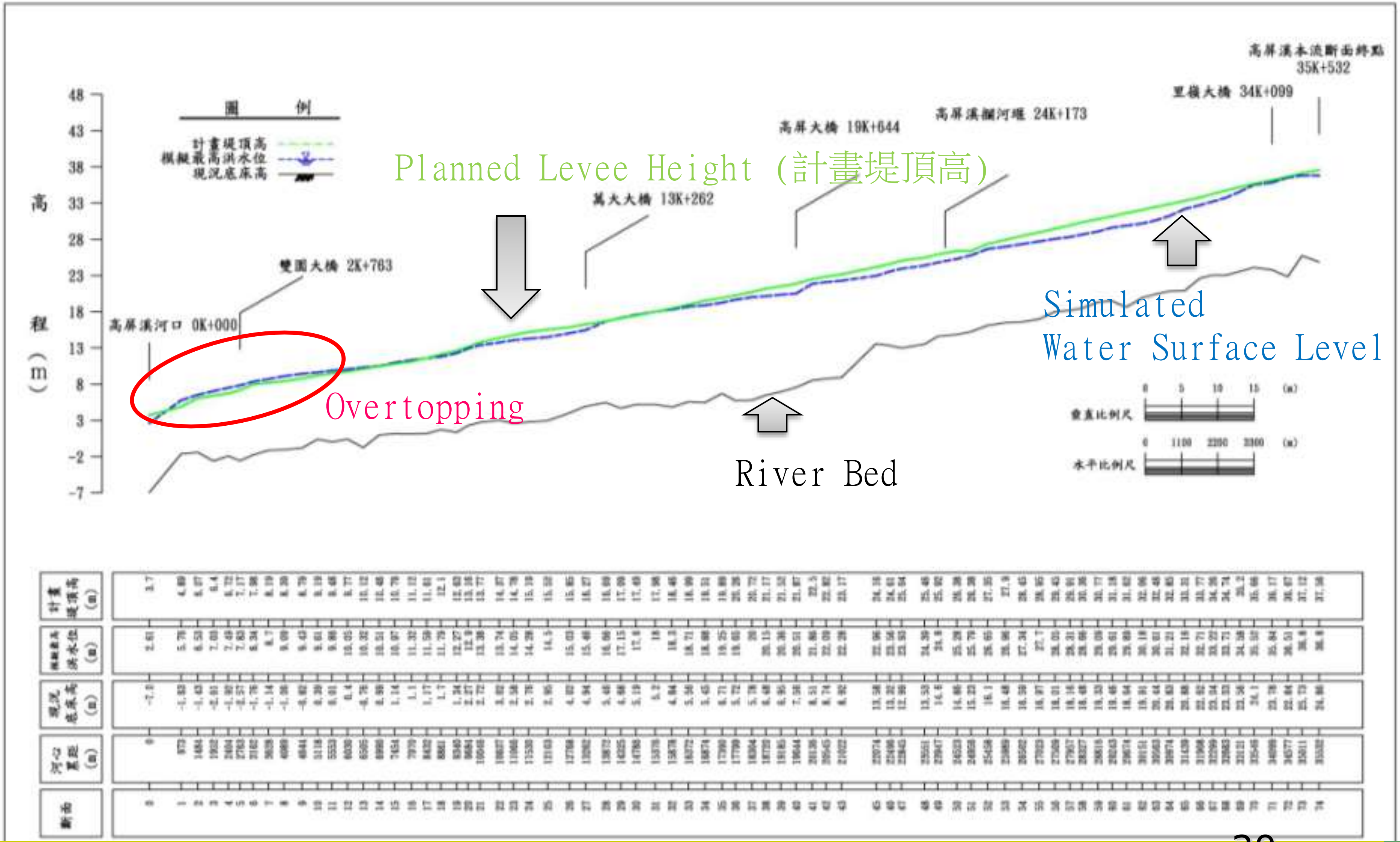
Map of boundaries



Discharge increase due to Climate Change

Watershed	Control point	Designed $(Q_{100})(1)$	A1B Simulated $(Q_{100})(2)$	(2)/(1)
Kaoping River 本流	Jiou cyu-tang (九曲堂站)	26,800	41,435	155%
Laonnog River 荖濃溪	Li gang Bridge(里港大橋)	21,100	30,582	145%
	Confluence of Laonnog River and Ailiao River (荖濃溪與隘寮溪合流前)	14,200	19,998	141%
	Laonung Bridge(新發大橋)	9,240	13,068	141%
Qishan River 旗山溪	Exit of Qishan (旗山溪出口)	7,780	10,540	135%
	Yuemei (月眉站)	5,990	8,275	138%
Ailiao River 隘寮溪	Exit of Ailiao River (隘寮溪出口)	8,600	11,133	129%
	Sandimen (三地門站)	6,150	8,513	138%

Koaping River A1B-100yr-return-period Water Surface Level



Planned Levee Height (計畫堤頂高)

Overtopping

Simulated Water Surface Level

River Bed

Reach of Overbank and Inefficient Free Board

Watershed		A1B
Kaoping River 高屏溪本流	Overbank	19
	Inefficient free board	46
Laonnog River 荖濃溪	Overbank	4
	Inefficient free board	15
Qishan River 旗山溪	Overbank	6
	Inefficient free board	17
Ailiao River 隘寮溪	Overbank	1
	Inefficient free board	9
Total	Overbank	30
	Inefficient free board	87

4.Preliminary Vulnerability and Risk Evaluation

Risk Matrix

Risk Matrix

水災風險程度

$$R = H \times V$$

Where, R：Risk (風險), presented by Risk Matrix
H：Hazard(危險度)Hazard
V：Vulnerability(脆弱度)

Hazard危險度

Vulnerability 脆弱度

	Very low (1)	Low (2)	Medium (3)	High (4)	Very high (5)
Very low (1)	(1)	(2)	(3)	(4)	(5)
Low (2)	(2)	(4)	(6)	(8)	(10)
Medium (3)	(3)	(6)	(9)	(12)	(15)
High (4)	(4)	(8)	(12)	(16)	(20)
Very high (5)	(5)	(10)	(15)	(20)	(25)

- ➢Relative Hazard/ Vulnerability
- ➢相對危險等級/脆弱度等級

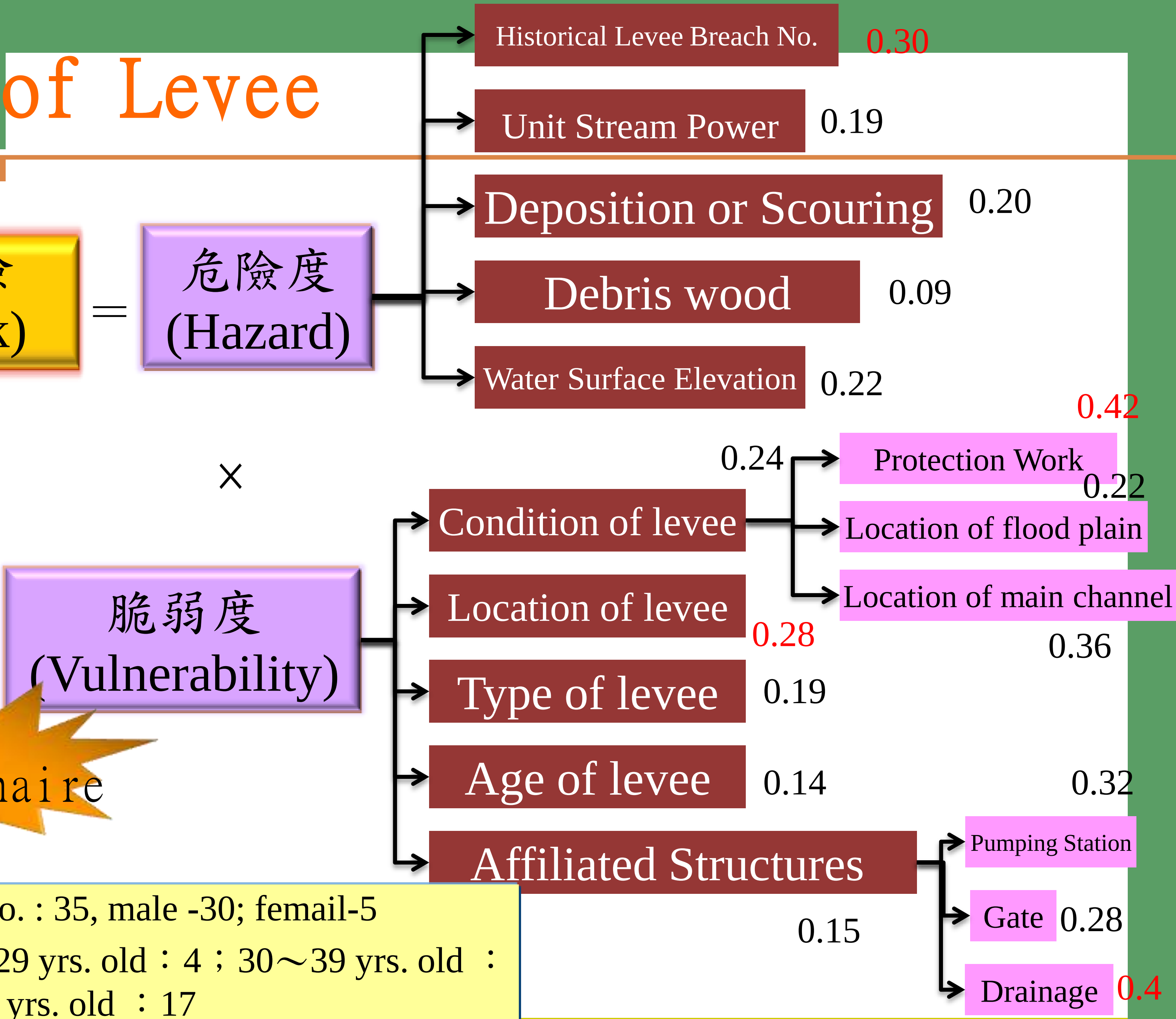
Very high	5	Top20%
High	4	Top20～40%
Medium	3	Top40～60%
Low	2	Bottom20-40%
Very low	1	Bottom20%

- ➢Relative Risk(相對風險等級)

Very high	>20	Top20%
High	14~20	Top20～40%
Medium	10~14	Top40～60%
Low	5~9	Bottom20-40%
Very low	1~4	Bottom20%

Risk of Levee

堤防護岸因子權重結果



風險 (Risk) ＝ 危險度 (Hazard) × 脆弱度 (Vulnerability)

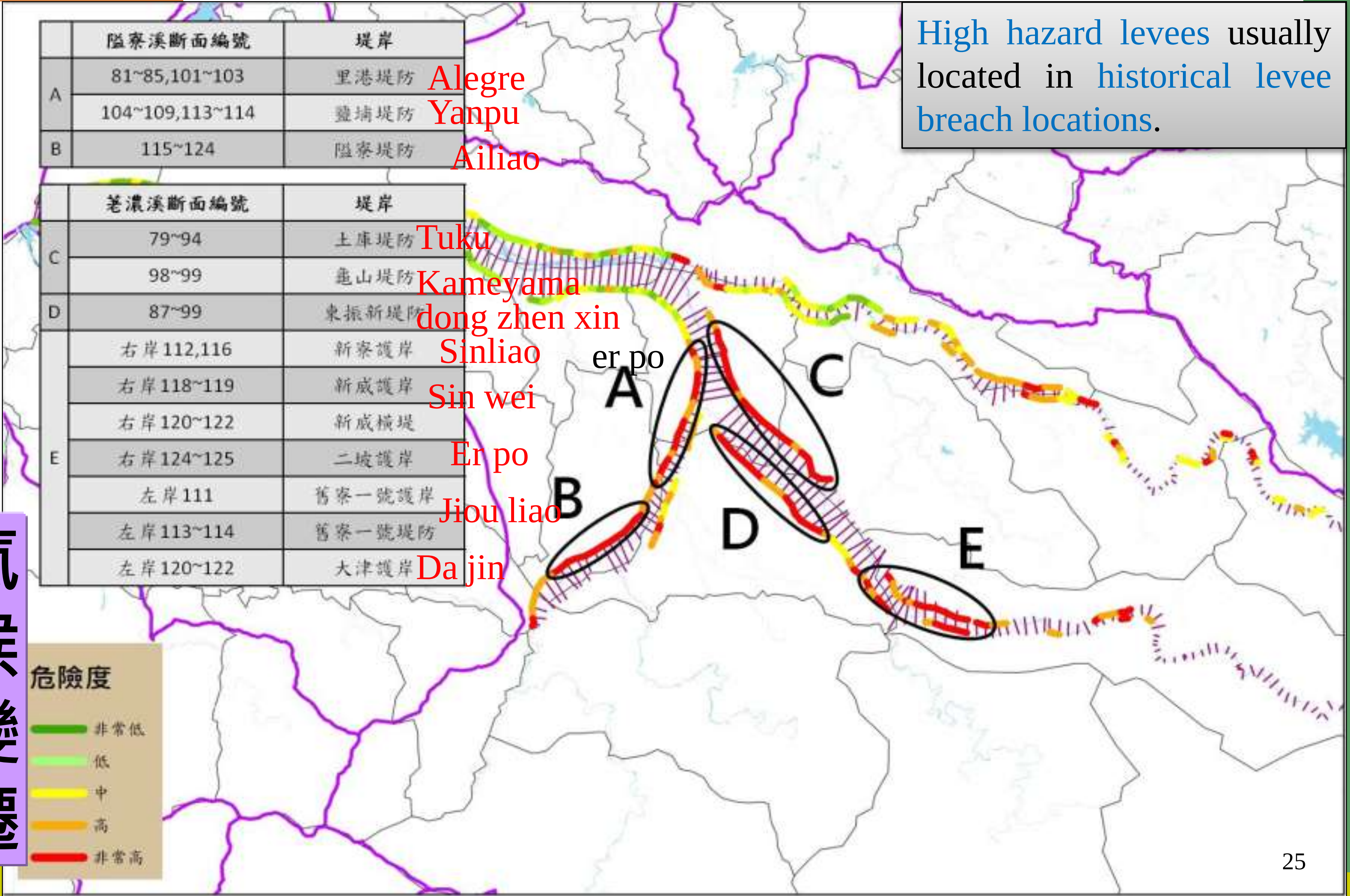
Questionnaire

- Samples no. : 35, male -30; femail-5
- Age：20-29 yrs. old：4；30～39 yrs. old ：14人；> 40 yrs. old ：17

Hazard of Levee

堤防護岸危險度圖

氣候變遷



	隘寮溪斷面編號	堤岸
A	81~85,101~103	里港堤防
	104~109,113~114	鹽埔堤防
B	115~124	隘寮堤防

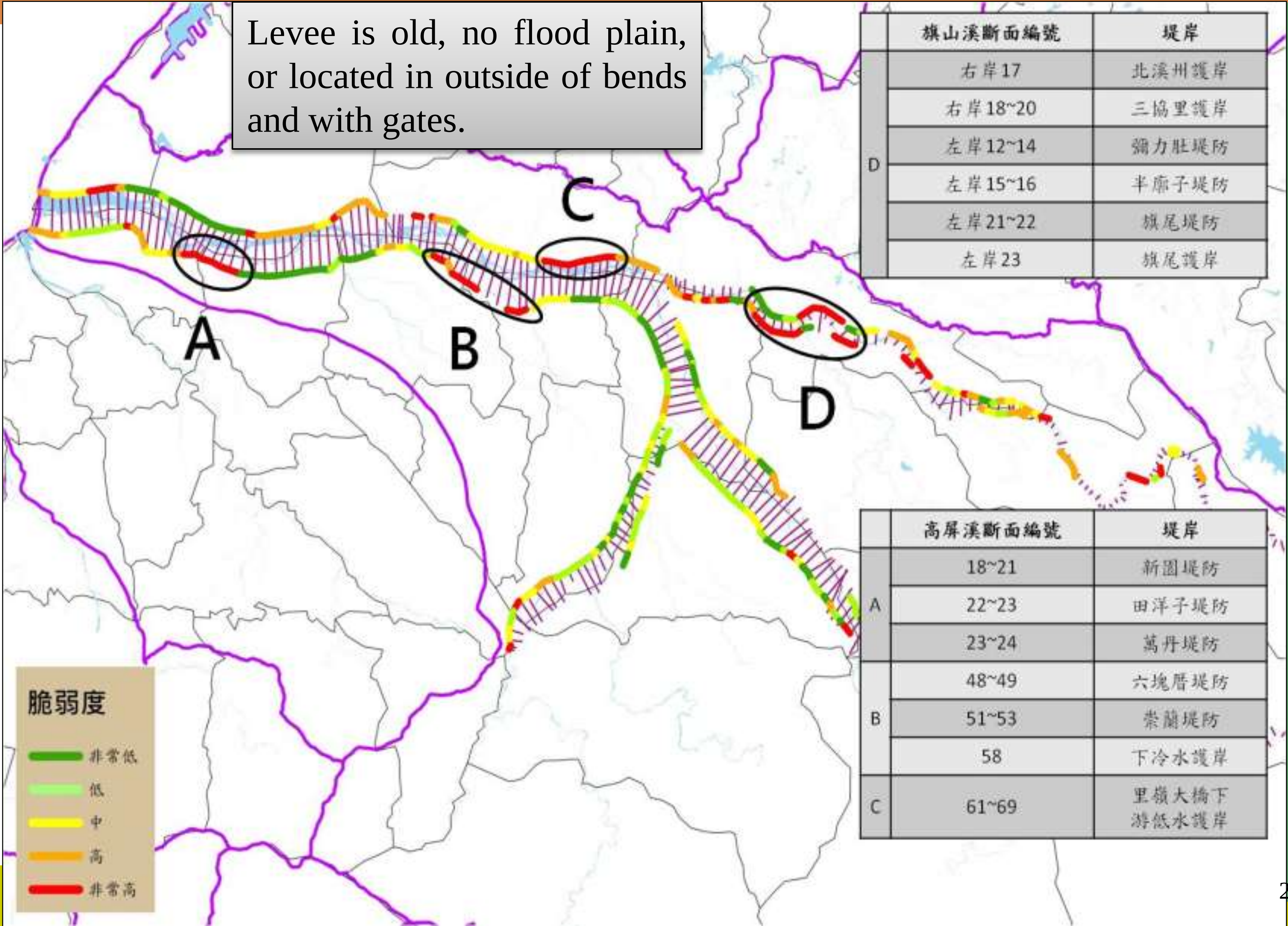
	荖濃溪斷面編號	堤岸
C	79~94	土庫堤防
	98~99	龜山堤防
D	87~99	東振新堤防
E	右岸112,116	新寮護岸
	右岸118~119	新威護岸
	右岸120~122	新威橫堤
	右岸124~125	二坡護岸
	左岸111	舊寮一號護岸
	左岸113~114	舊寮一號堤防
	左岸120~122	大津護岸

High hazard levees usually located in historical levee breach locations.

Vulnerability of Levee (Now)

堤防護岸脆弱度圖(高屏溪主流)

Levee is old, no flood plain, or located in outside of bends and with gates.



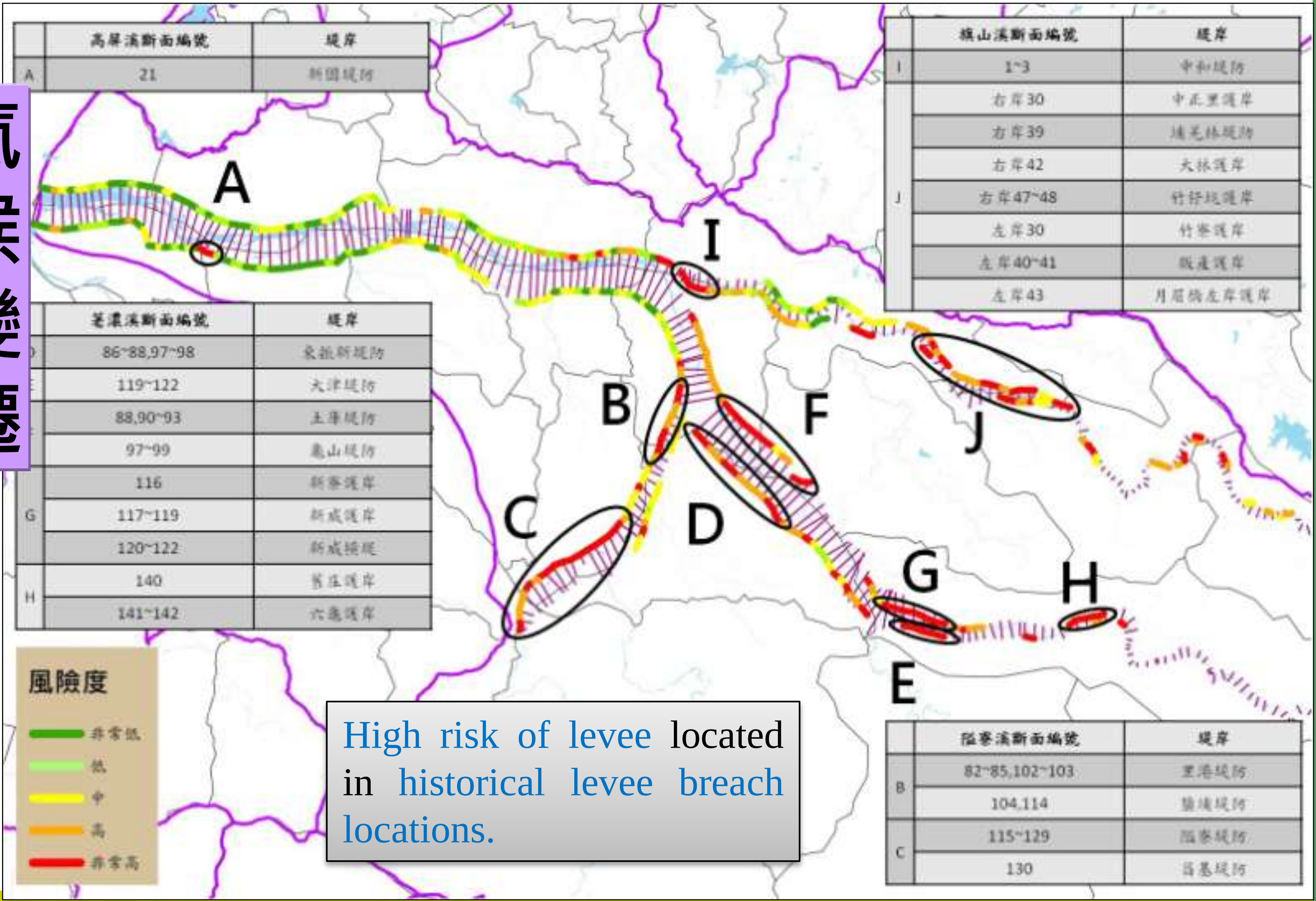
	旗山溪斷面編號	堤岸
D	右岸17	北溪州護岸
	右岸18~20	三協里護岸
	左岸12~14	彌力肚堤防
	左岸15~16	半廍子堤防
	左岸21~22	旗尾堤防
	左岸23	旗尾護岸

	高屏溪斷面編號	堤岸
A	18~21	新園堤防
	22~23	田洋子堤防
	23~24	萬丹堤防
B	48~49	六塊厝堤防
	51~53	崇蘭堤防
	58	下冷水護岸
C	61~69	里嶺大橋下 游低水護岸

Risk of Levee due to Climate Change

堤防護岸風險度圖(高屏溪主流)

氣候變遷



	高屏溪斷面編號	堤岸
A	21	新圍堤防

	荖濃溪斷面編號	堤岸
D	86~88,97~98	東振新堤防
E	119~122	大津堤防
	88,90~93	土庫堤防
	97~99	龜山堤防
G	116	新豐護岸
	117~119	新威護岸
	120~122	新威[illegible]堤
H	140	舊庄護岸
	141~142	六龜護岸

	旗山溪斷面編號	堤岸
I	1~3	中和堤防
J	右岸30	中正里護岸
	右岸39	埔羌林堤防
	右岸42	大林護岸
	右岸47~48	竹圩圳護岸
	左岸30	竹寮護岸
	左岸40~41	旗尾護岸
	左岸43	月眉橋左岸護岸

	隘寮溪斷面編號	堤岸
B	82~85,102~103	里港堤防
	104,114	鹽埔堤防
C	115~129	隘寮堤防
	130	昌基堤防

High risk of levee located in historical levee breach locations.

5. Action Plan

Action Plan

◆**Objective**

This action plan mainly aims on **non-structural measures and necessary structural measures**. It is based on the existed hydraulic structures for improvement and enhancement. The objective of this action plan：

Important reach of Kaoping River is not overflowed when encountering discharge of return period of 100 years (Q_{100})due to A1B scenario.

◆**Time Span**

- **Near(2012-2039)**

Action Plans

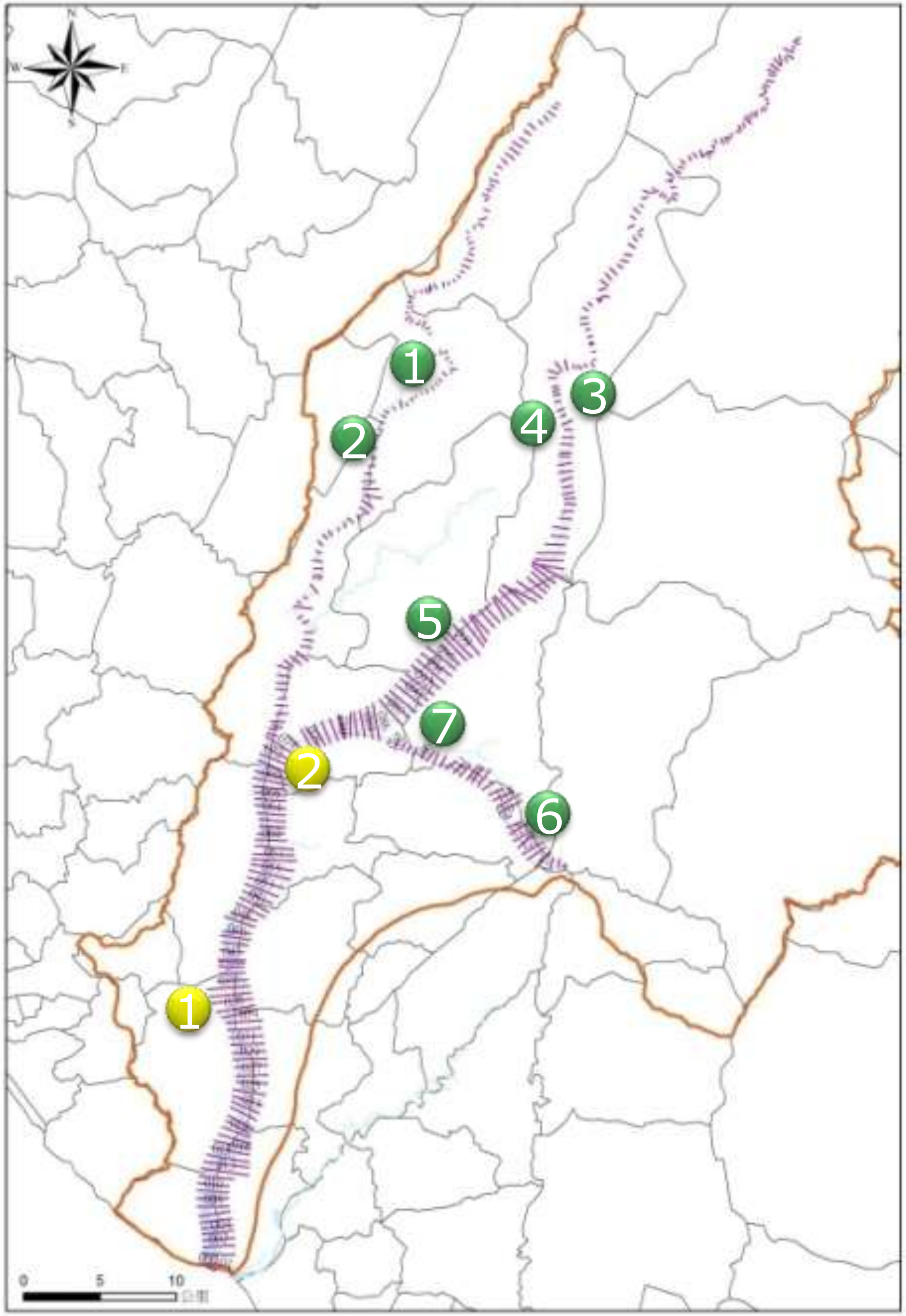
	Plan A	Plan B
structural measures	Upstream-7 overflow area	Dredge 1m deep of main stream
	Middle/downstream 2 retention basins	Upstream-4 overflow area
non-structural measures	-Evacuation Assistant -Evacuation drill -Flood gate panels	-Evacuation Assistant -Evacuation drill -Flood gate panels
Total Cost	0.65 billion NTD	10.2 billion NTD

Plan A-Locations

- 方案1

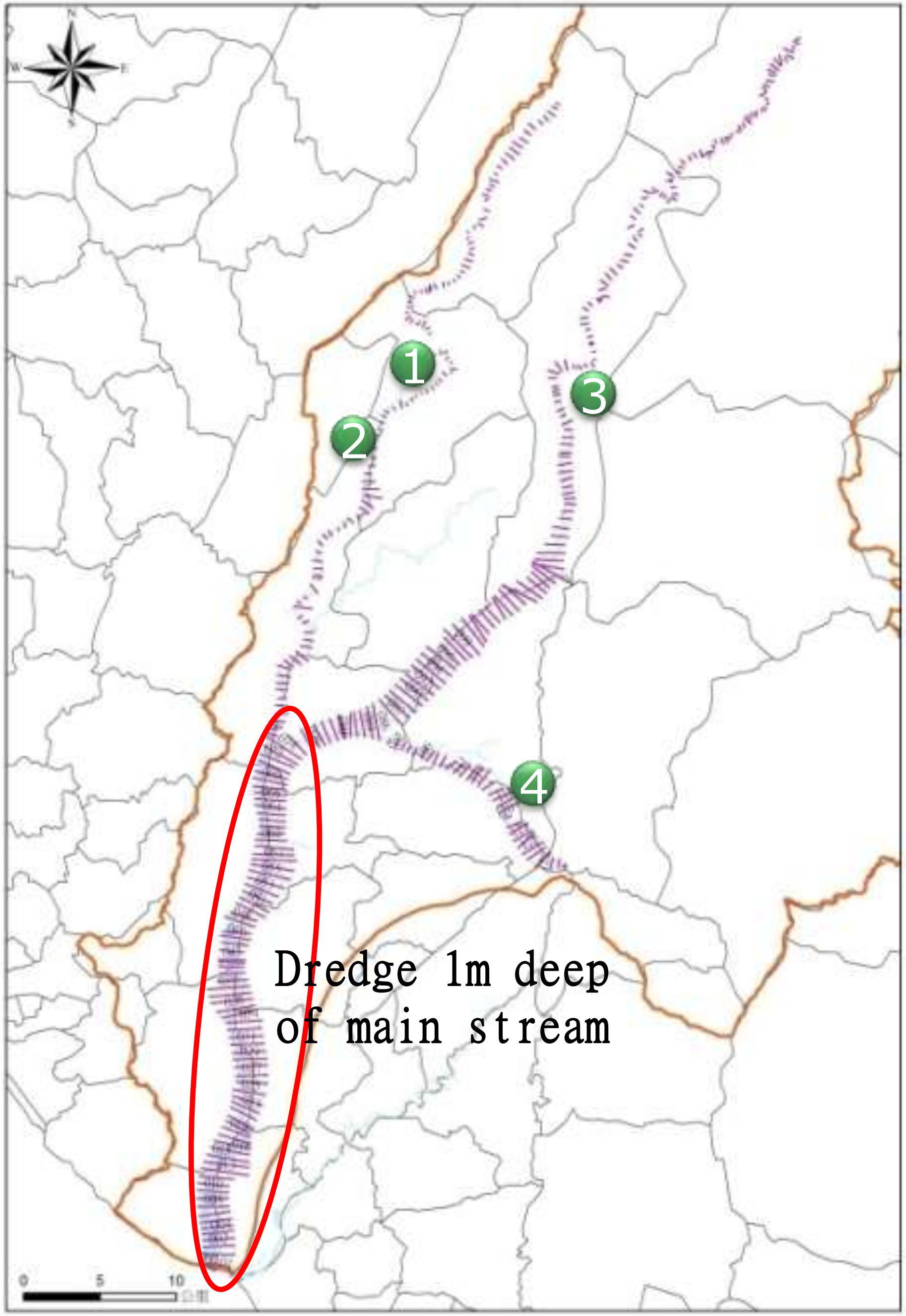
-Upstream-7 overflow area ①②③④⑤⑥⑦

-Middle/downstream 2 retention basins ①②



Plan B-Locations

- 方案2
  - Upstream-4 overflow area ①②③④
  - Dredge 1m deep of main stream (red circled)



Difference between Plan A and B

<table>
<tr><th colspan="6">Original A1B</th></tr>
<tr><th>Item/River</th><th>Mainstream</th><th>Laonnog</th><th>Qishan</th><th>Ailiao</th><th>Total</th></tr>
<tr><td>Insufficient free board</td><td>46</td><td>15</td><td>17</td><td>9</td><td>87</td></tr>
<tr><td>Overbank</td><td>19</td><td>4</td><td>6</td><td>1</td><td>30</td></tr>
<tr><td>Flooded Area</td><td colspan="5">565Km^{2}</td></tr>
<tr><td>No. of Evacuation Assistants</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td></tr>
<tr><th colspan="6">Plan A (Overflow Area+ Retention Basin)</th></tr>
<tr><td>Insufficient free board</td><td>5</td><td>4</td><td>2</td><td>5</td><td>16</td></tr>
<tr><td>Overbank</td><td>0</td><td>0</td><td>3</td><td>1</td><td>4</td></tr>
<tr><td>Flooded Area</td><td colspan="5">50Km^{2} (515Km^{2} reduced)</td></tr>
<tr><td>No. of Evacuation Assistants</td><td>50(人)</td><td>50(人)</td><td>50(人)</td><td>50(人)</td><td>200(人)</td></tr>
<tr><th colspan="6">Plan B (Overflow Area+ Main Stream Dredge 1m deep)</th></tr>
<tr><td>Insufficient free board</td><td>1</td><td>6</td><td>2</td><td>0</td><td>9</td></tr>
<tr><td>Overbank</td><td>0</td><td>0</td><td>1</td><td>0</td><td>1</td></tr>
<tr><td>Flooded Area</td><td colspan="5">20Km^{2} (545Km^{2} reduced)</td></tr>
<tr><td>No. of Evacuation Assistants</td><td>100(人)</td><td>100(人)</td><td>100(人)</td><td>100(人)</td><td>100(人)</td></tr>
</table>

6.Conclusions

Conclusion

- The simulated Q_{100} for A1B is about 1.3~1.55 times of planned Q .
- For A1B scenario, the risk of villages of middle and downstream of Kaoping River is increasing。
- Plan A (Upstream-7 overflow area+ Middle/downstream 2 retention) : the flooded area reduces 515Km^2, locations of insufficient freeboard reduces 82%, locations of overbnak reduces 86%, and costs 0.65 billion NTD。
- Plan B (Upstream-4 overflow area+ 1m dredge deep) : the flooded area reduces 515Km^2, locations of insufficient freeboard reduces 90%, locations of overbnak reduces 96%, and costs 10.2 billion NTD。

Thanks for your attention

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