Strengthening Adaptive Capacity of Water Supply Systems to Climate Change
- the Danshuei River Watershed




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Contents

Background

- Extensive development requires more resources and discharges more pollutants, which may degrade eco-environment.
- Sustainable development requires to meet the needs of both current and future generations.
- Development of sustainable watershed management plans is crucial, and changing climate is the most important challenge and should be seriously considered.

- Water resources engineering is designed according to physical rules and statistic information derived from historical observation.
- Those statistics are assumed to be constant in design process.

- Climate not only changes but also is changing.
  - Can hydrological statistics be constants?
  - Can water resources systems still provide reliable services in future?
  - How and what should we do?

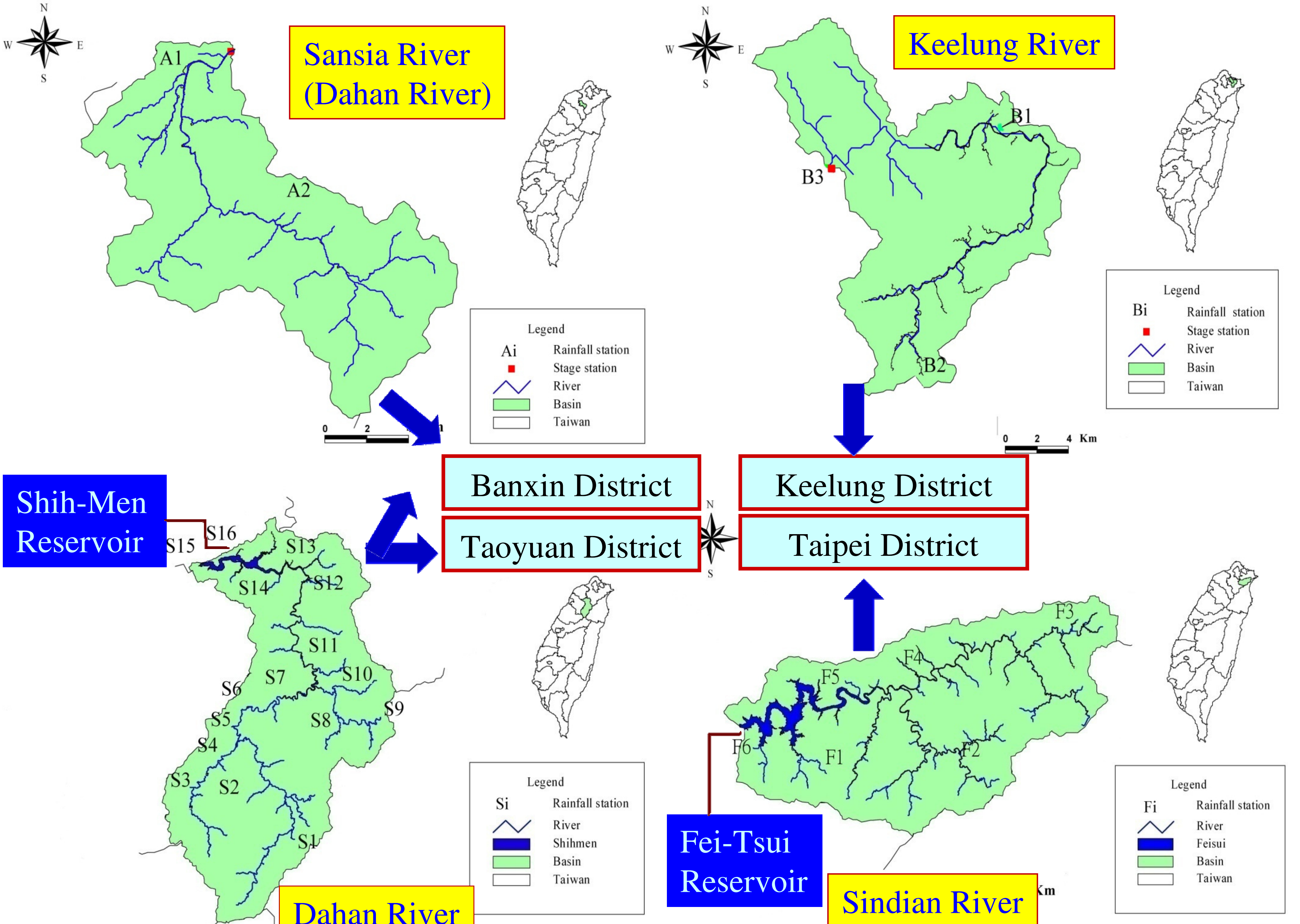
Goals of our study

- Evaluating the reliability of water supply systems.
- Identifying effective strategies to strengthen adaptive capacity of water supply systems, which can
  - Continuously support social and economic developments and
  - Sustainably conserve eco-environment

Study Area

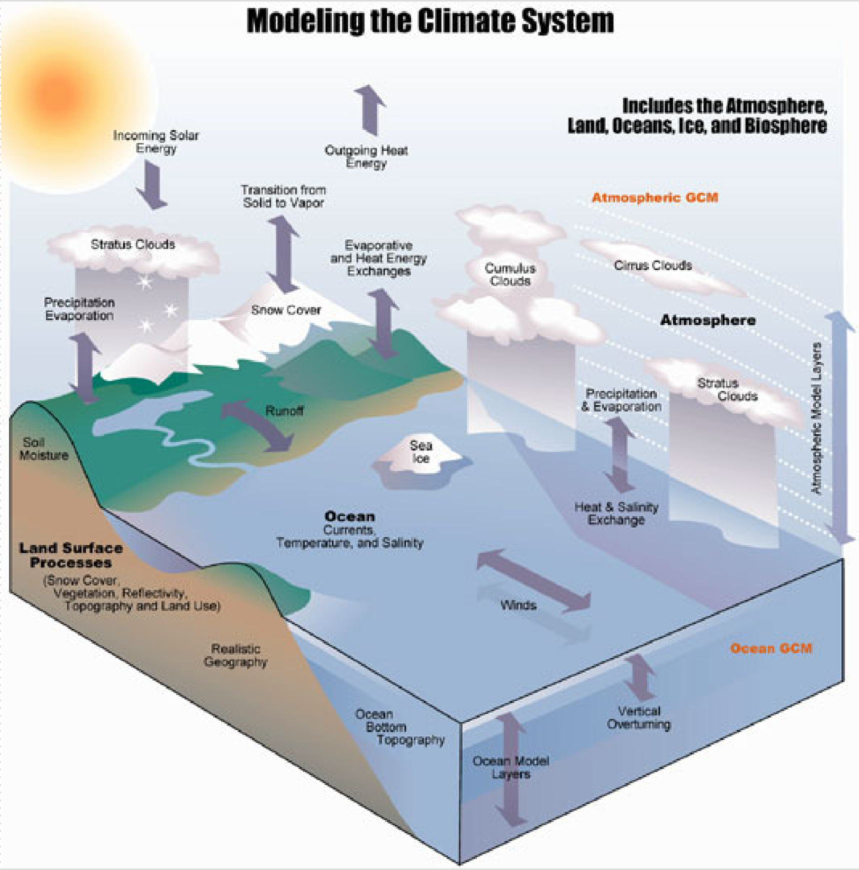
- the Dan-Shuei River Watershed

- Three major Tributaries
  - Sindian River
  - Dahan River
  - Keelung River
- Two reservoirs
  - Shih-Men Reservoir
  - Fei-Tsui Reservoir



(Figures provided by Prof. Li)

Analysis of Current Hydrology



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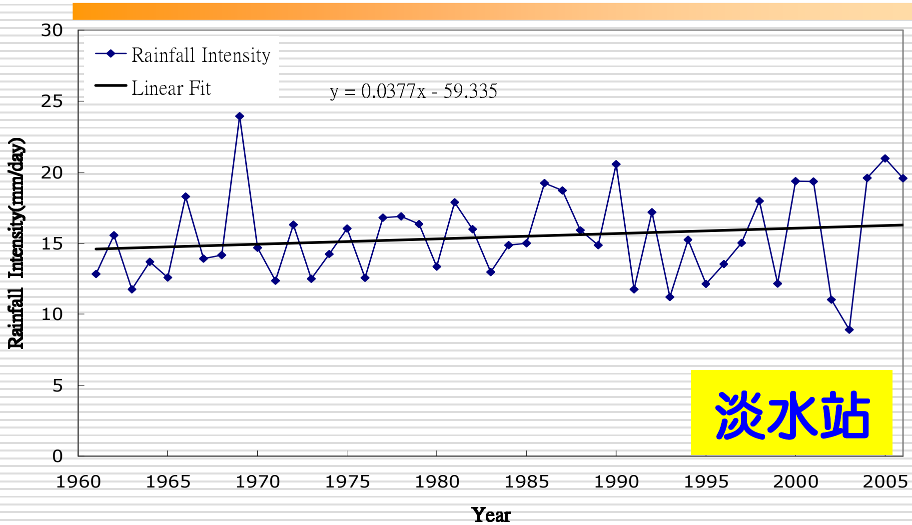
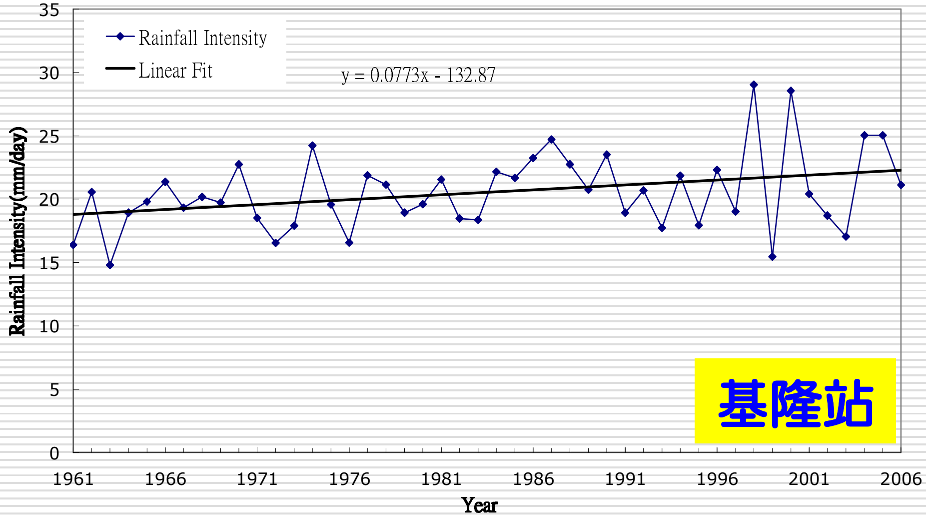
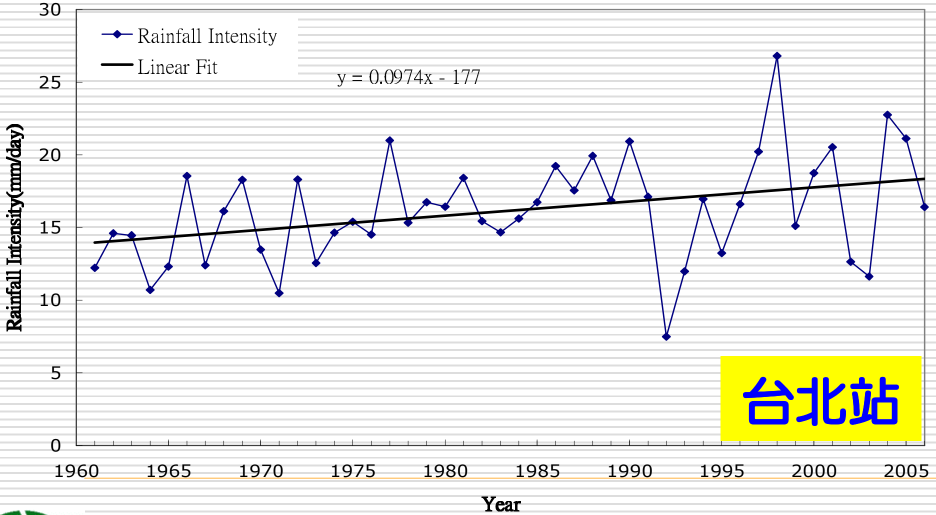
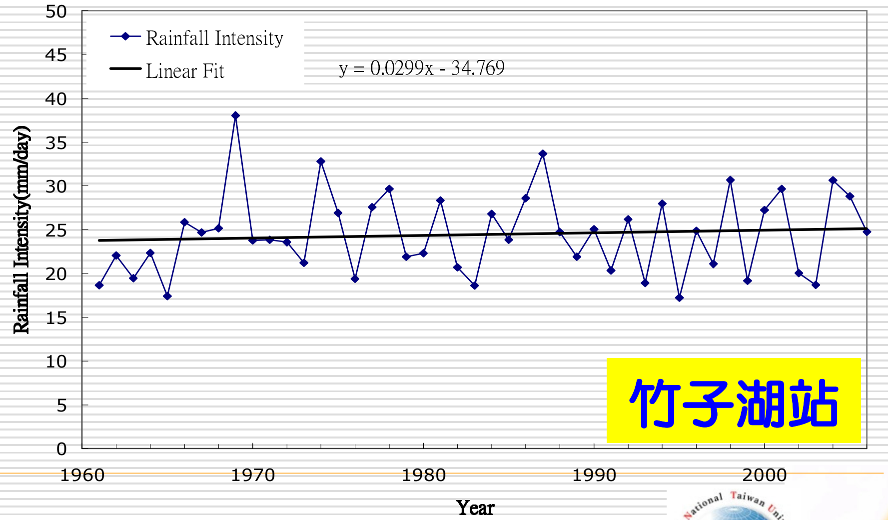
Trend of Rainfall Intensity

[Prof. Li (李明旭), NCU]

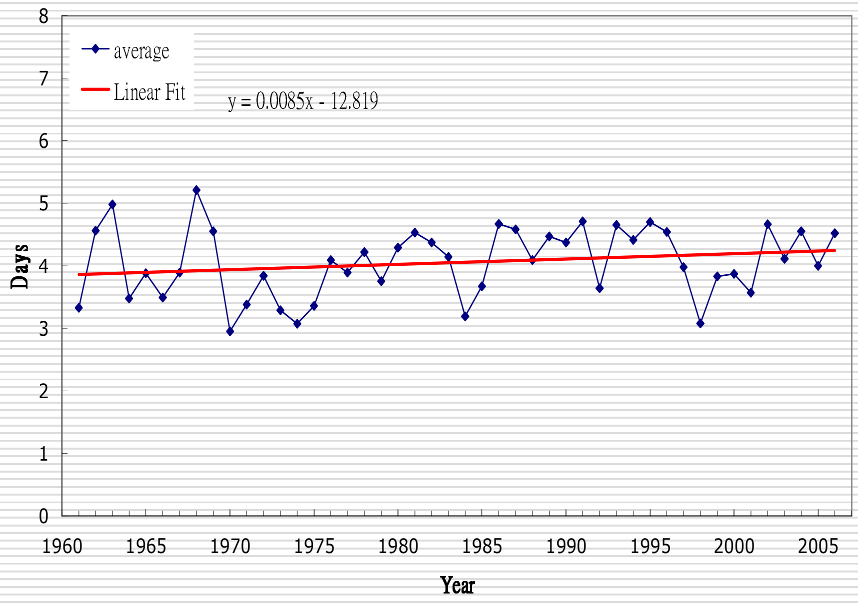




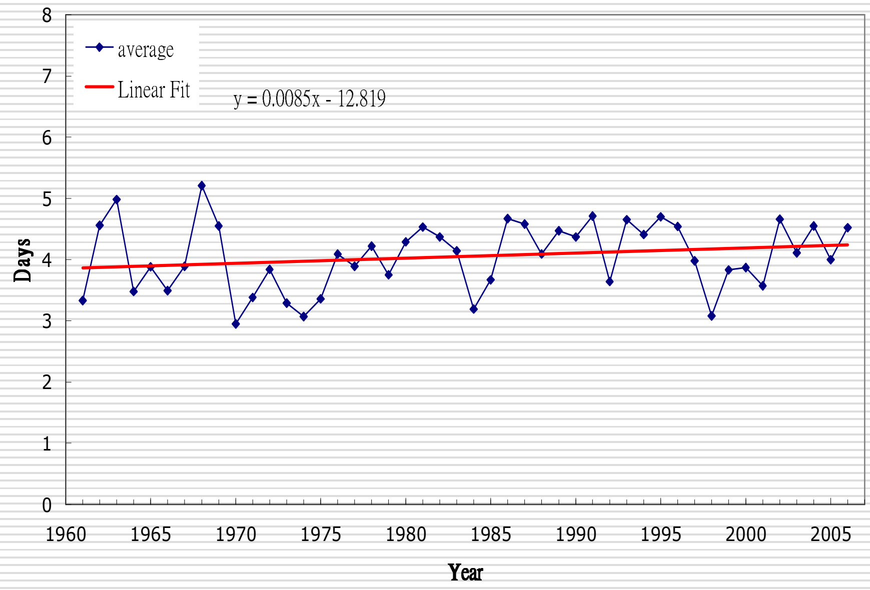




Trend of Dry Day durations



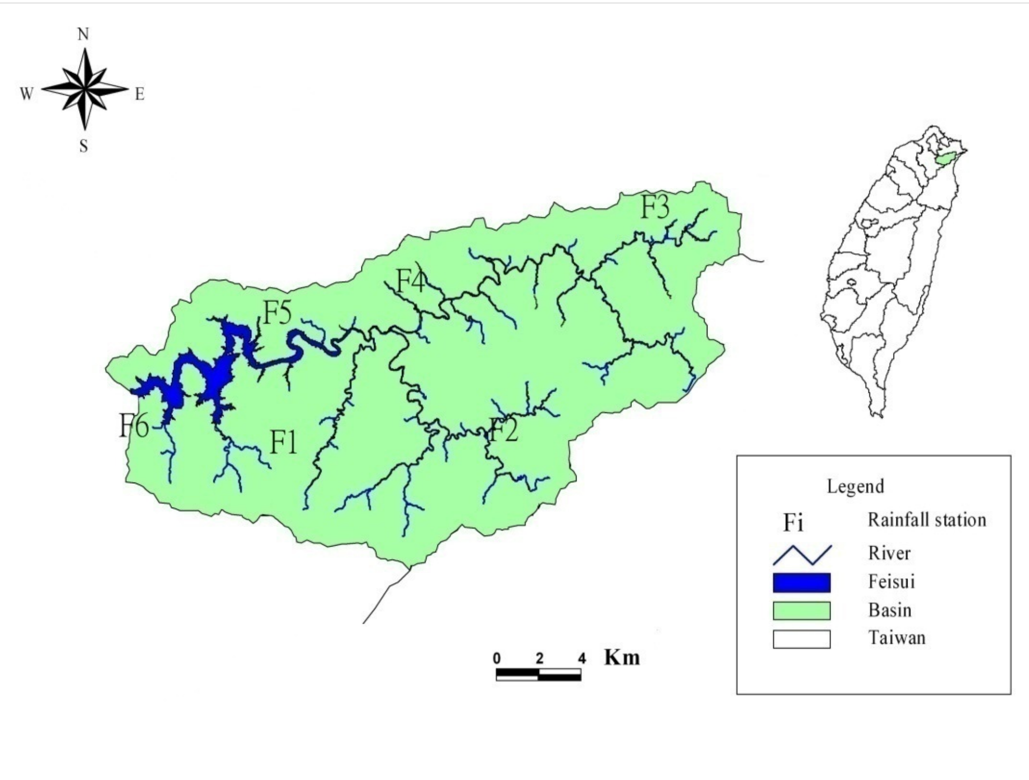
Taipei



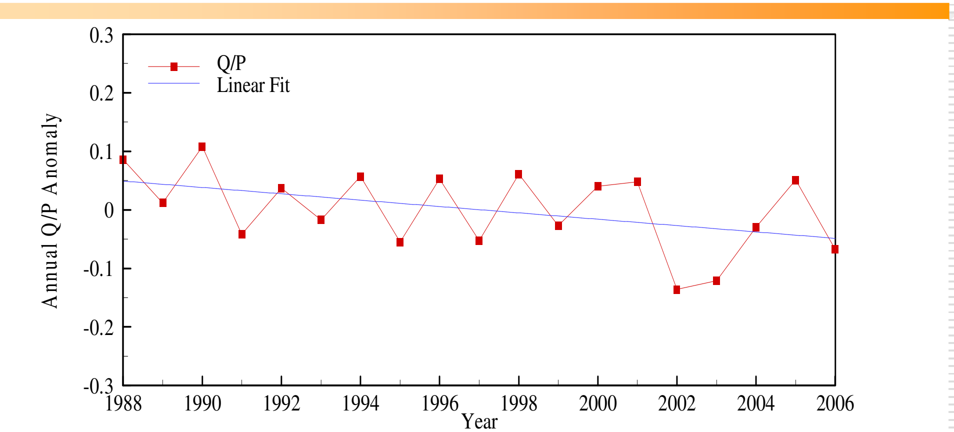
Dansheui

Trend of flow/rainfall ratio

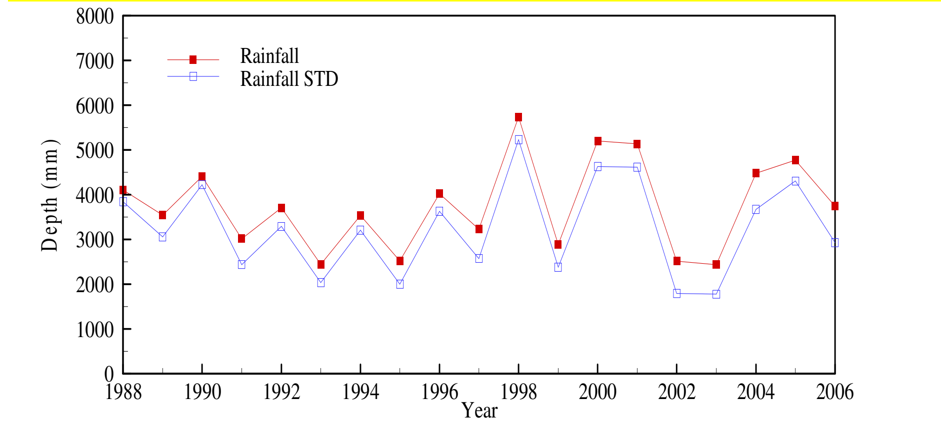
Fei-Tsui Reservoir [Prof. Li (李明旭), NCU]



集水區雨量站之相關位置圖



集水區年逕流比值距平圖



集水區年降雨深度與年逕流深度歷線圖

Assessment of Climate Change Impacts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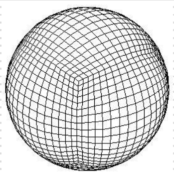
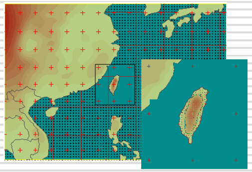
Methodology

- Development of systematic tools to identify vulnerable components of water supply systems
  - Natural components
    - Atmosphere - climate and weather
    - Hydrosphere - Stream flows, groundwater
  - Human components
    - Facility – reservoirs, treatment plants, distribution systems
    - Management plans – demands and operations

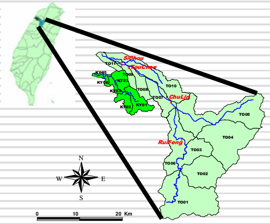
Procedures



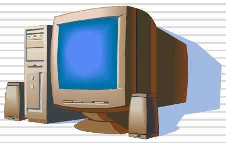
GCM Predictions



Downscaling

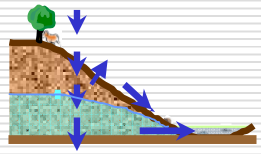


Future
Climate Scenarios

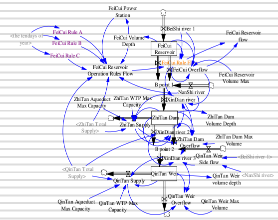


Weather Generation

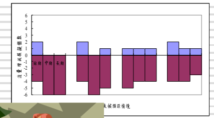
Hydrological Model



Water Supply System
Dynamics Model

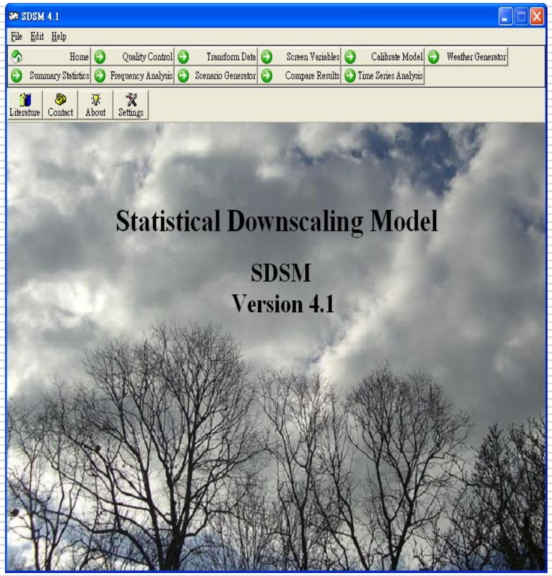


Impact Inoformation
for Decision Making



Downscaling Methods

- Simple Downscaling
  - Climate changes of a local area are assumed the same as the nearest grid point
- Statistical Downscaling
  - Finding the statistical relationships between regional climate and local climate.



Future Climate Scenarios

	Simple Downscaling	SDSM
GCMs	CGCM2 ECHAM4 HADCM3 CCSR/NIES R30(GFDL) CSIRO-Mk2	HADCM3
SRES	A2、B2	A2、B2

Impacts on Stream Flows

[Prof. Yu (游保杉), NCKU]

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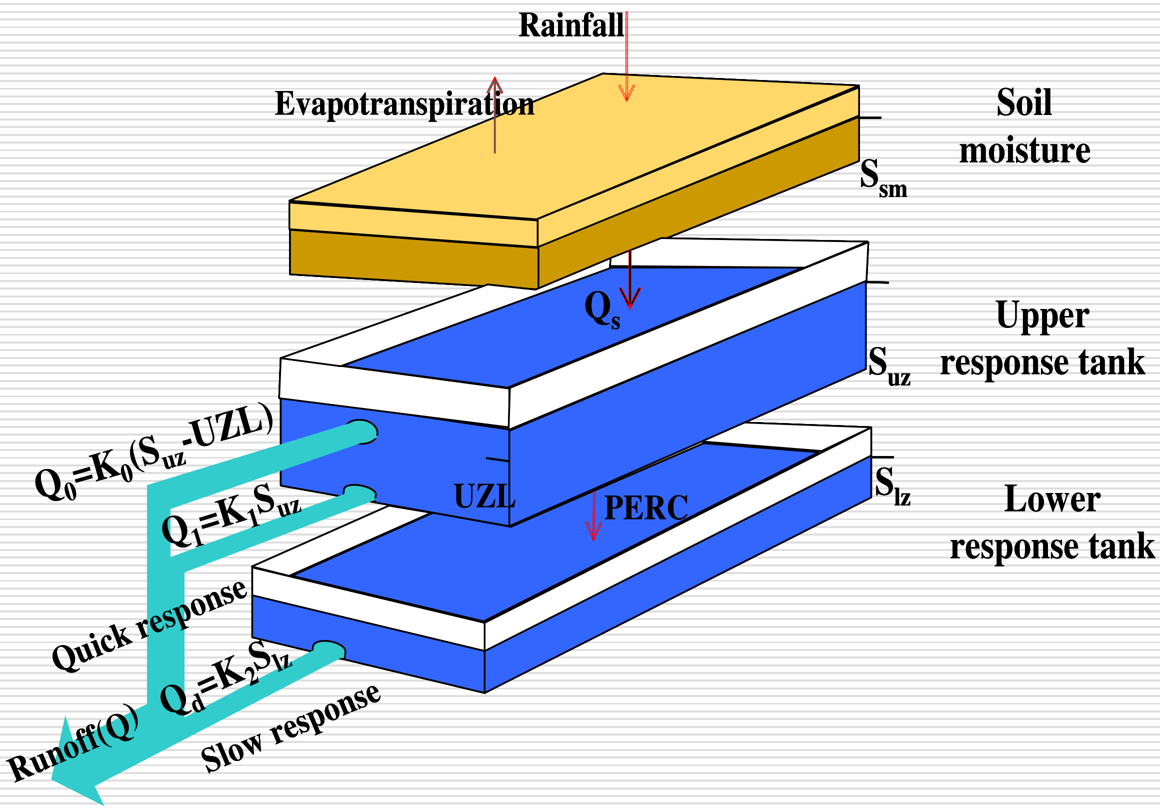
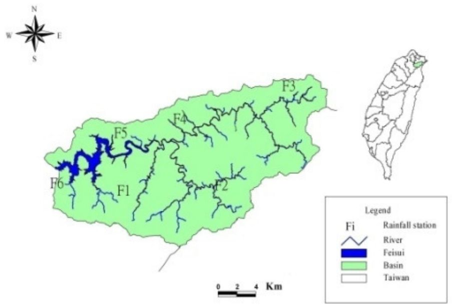
HBV Model

- Parameters
  - *FC*(Field Capacity)
  - β 、*LP* (Parameter)
  - *UZL*(Outflow height)
  - *Recession Coefficient*
    - K_0 (UZL)
    - K_1 (upper tank)
    - K_2 (lower tank)
  - *Ce* (coefficient of ET)
  - *PERC* (Percolation)

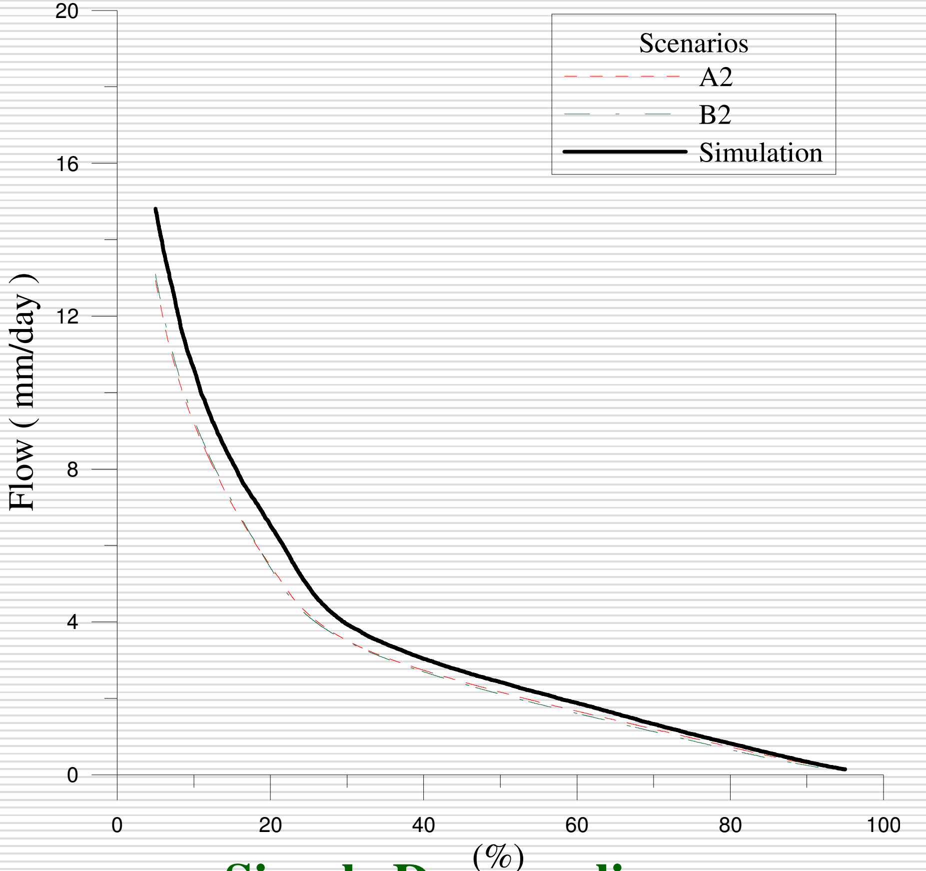


Impacts on Stream Flows

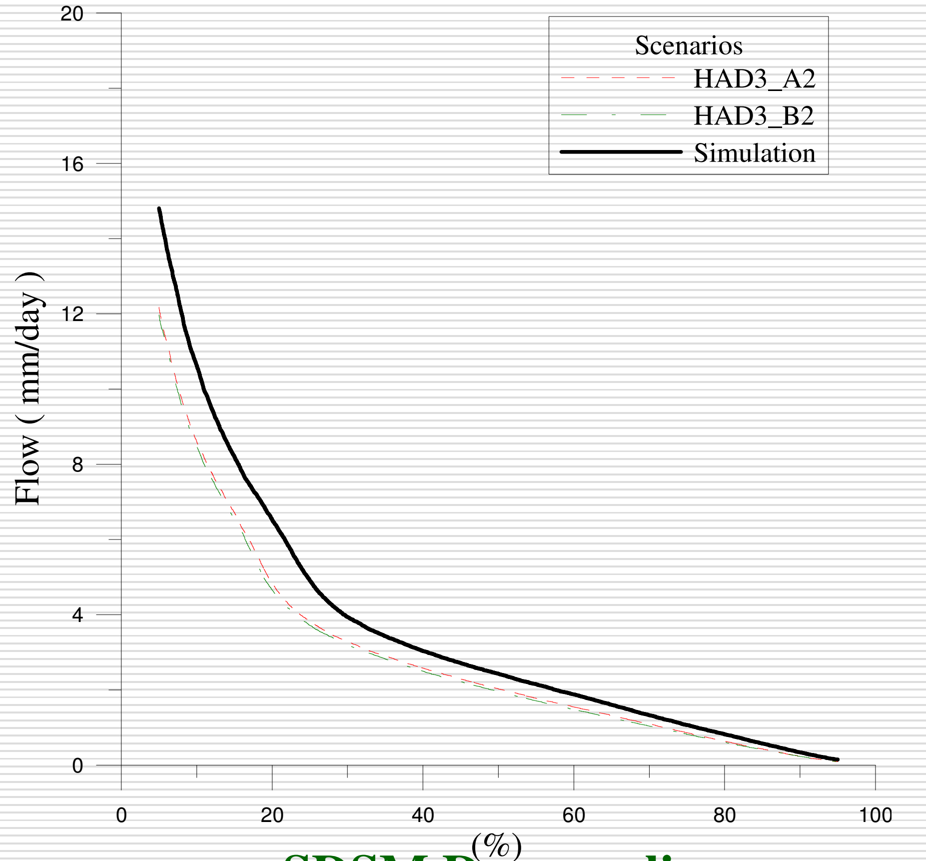
Dry Period [Prof. Yu (游保杉), NCKU]



- Fei-Tsui Reservoir Inflows



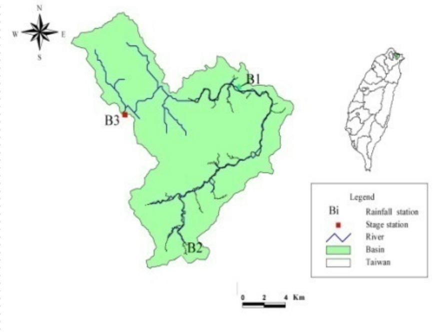
Simple Downscaling



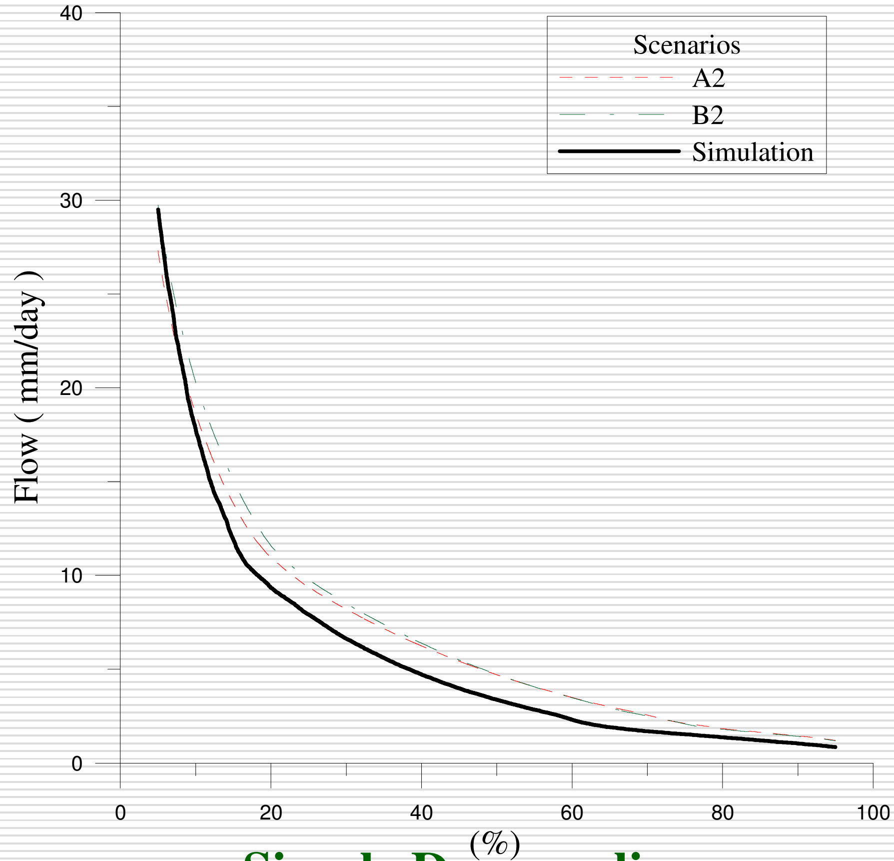
SDSM Downscaling

Impacts on Stream Flows

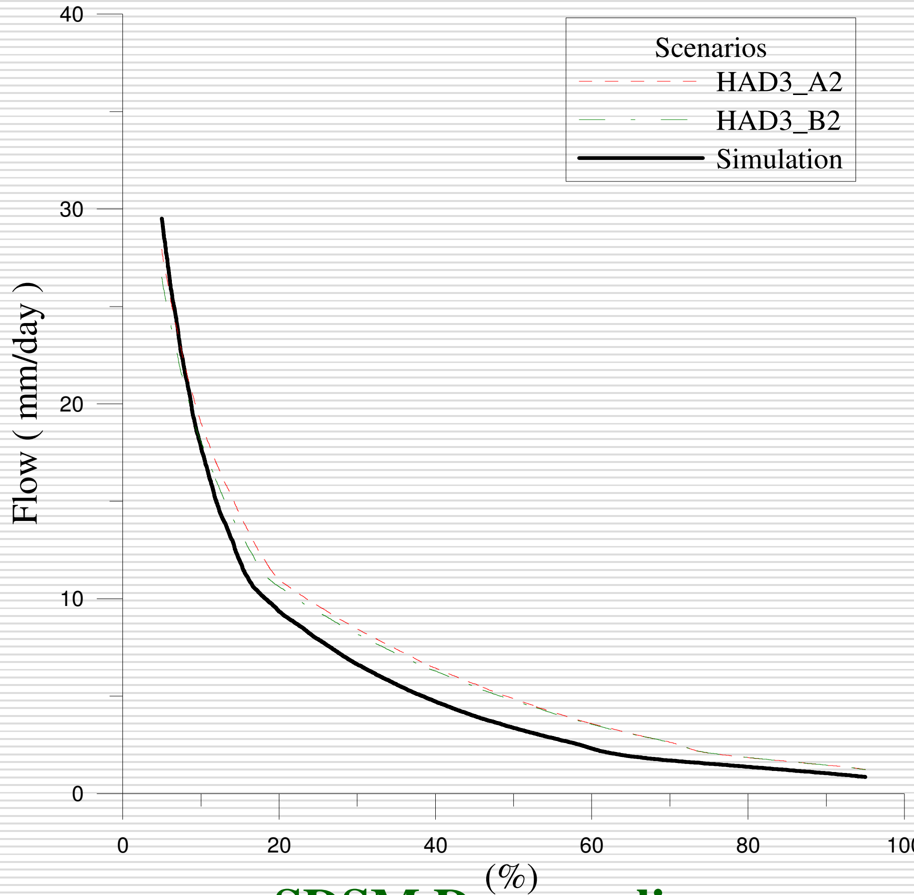
Wet Period [Prof. Yu (游保杉), NCKU]



- Keelung river



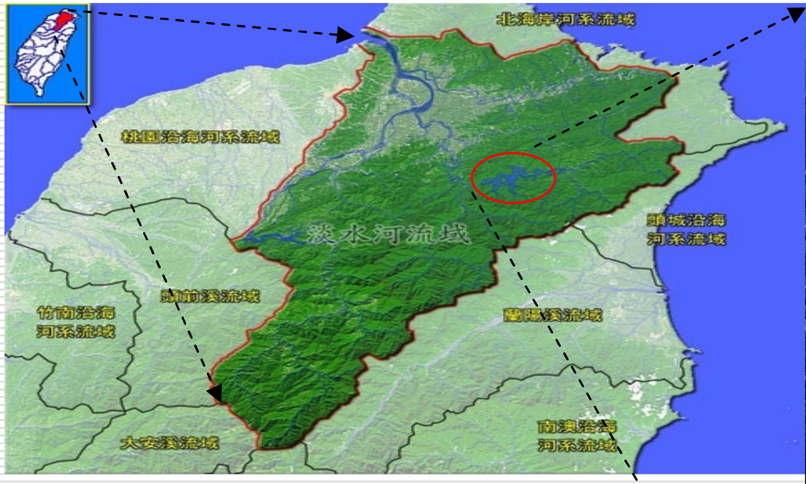
Simple Downscaling



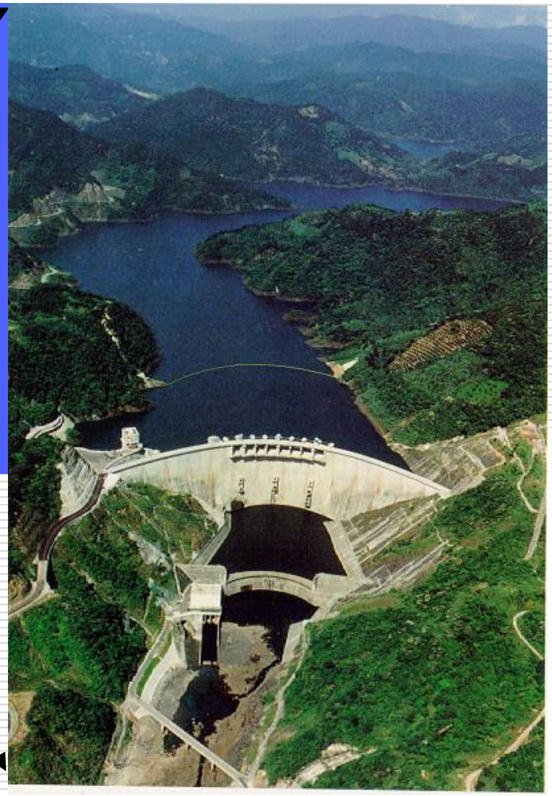
SDSM Downscaling

Impacts on Reservoir

(C.P. Tung)



（圖片來源：水利署十河局網站）



圖片來源：海洋大學河海工程系
http://wrm.hre.ntou.edu.tw/wrm/dss/resr/wk.htm

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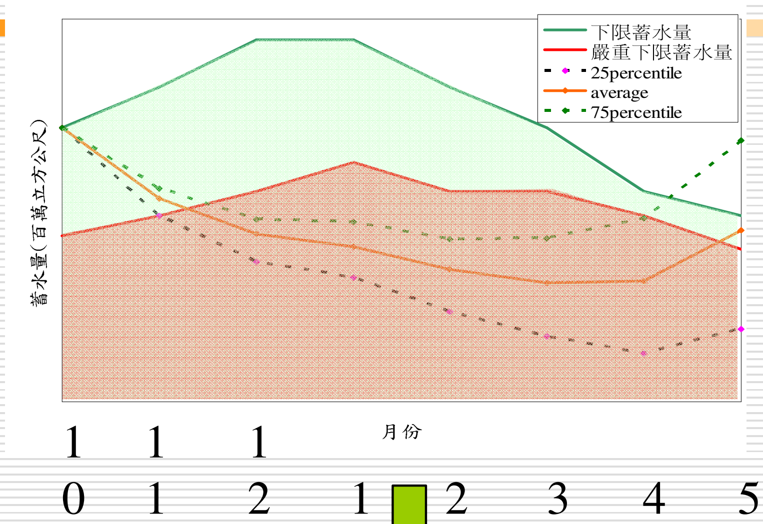
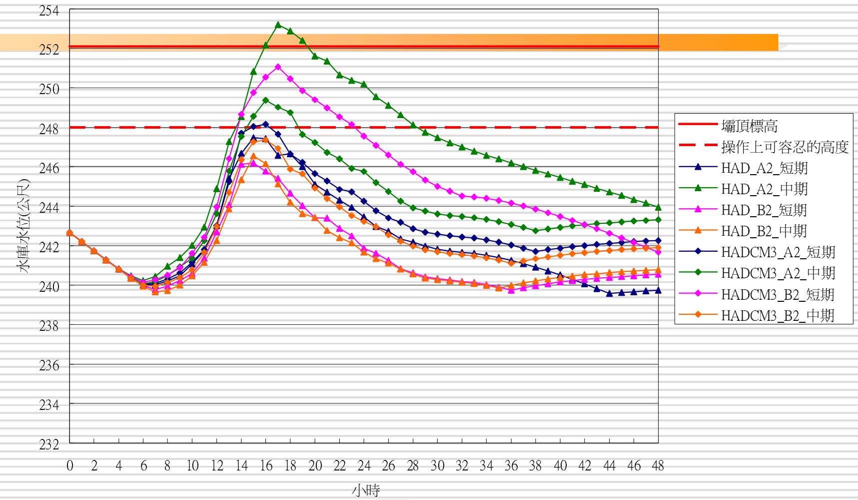
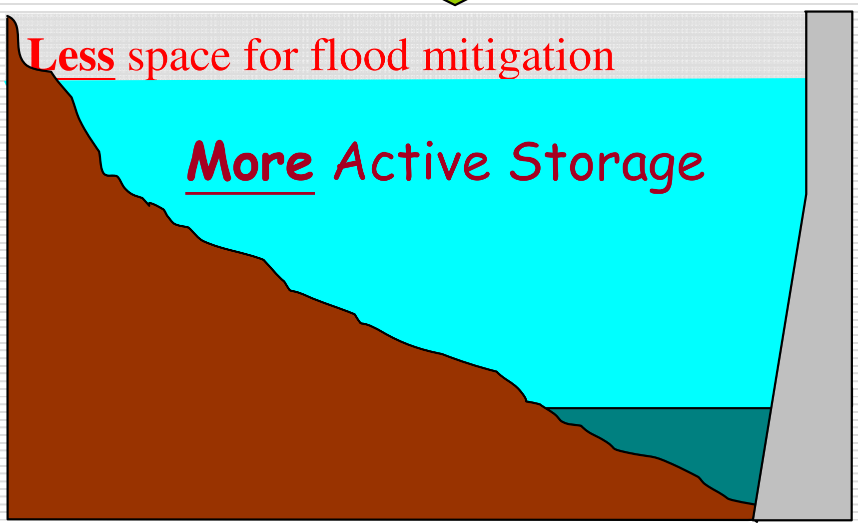
Water Supply

Flood Mitigation







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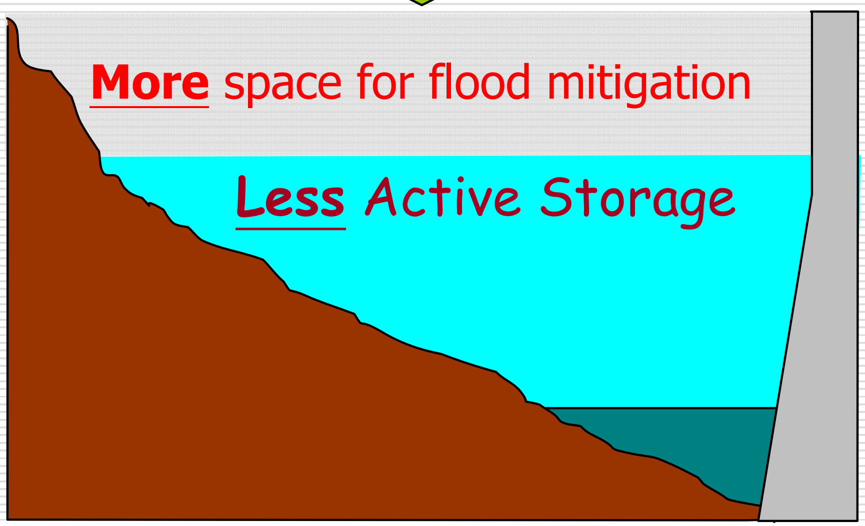
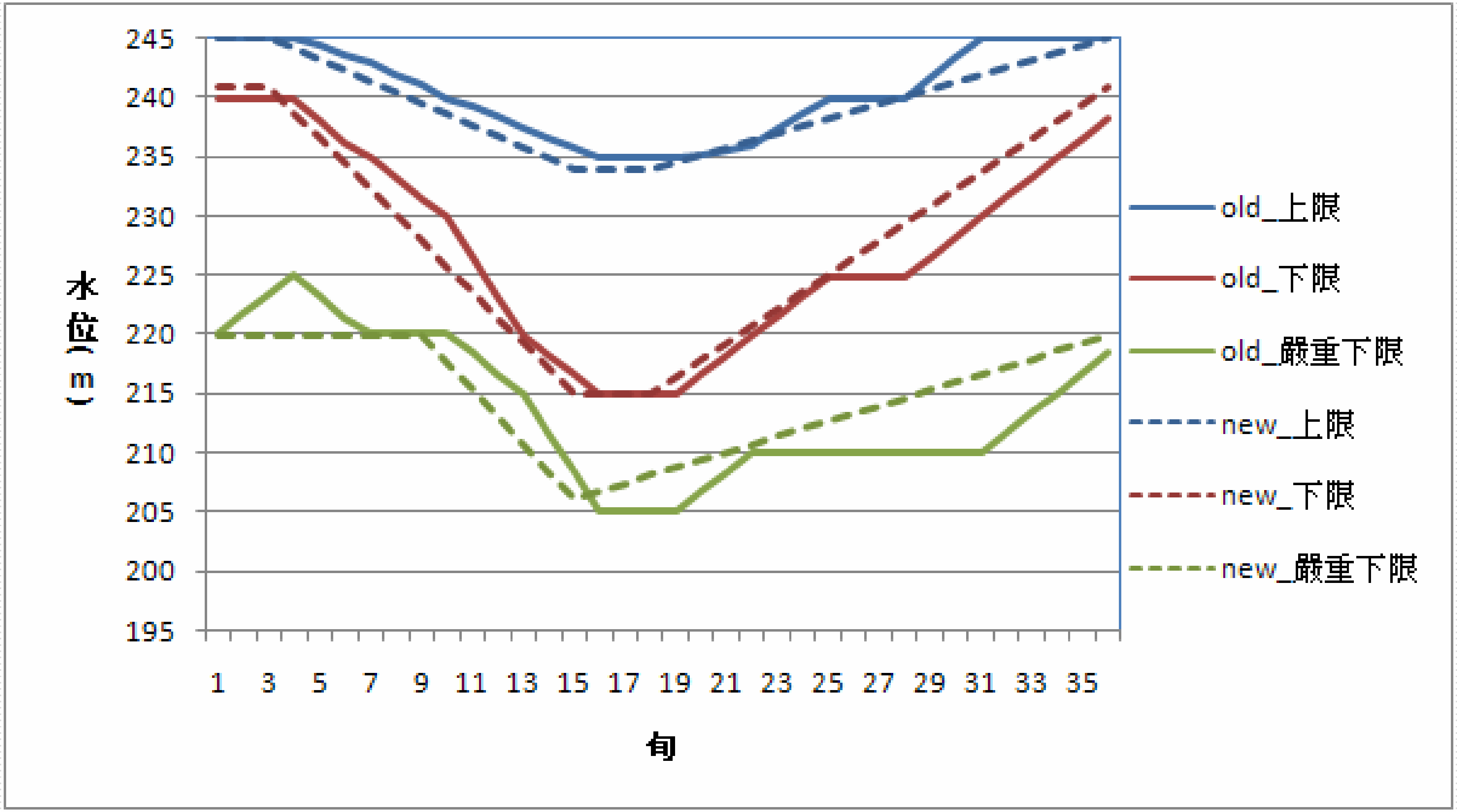


Modifications of Operational Rules due to More Extreme Events_HADCM3



Impacts on Water Supply

(C.P. Tung)

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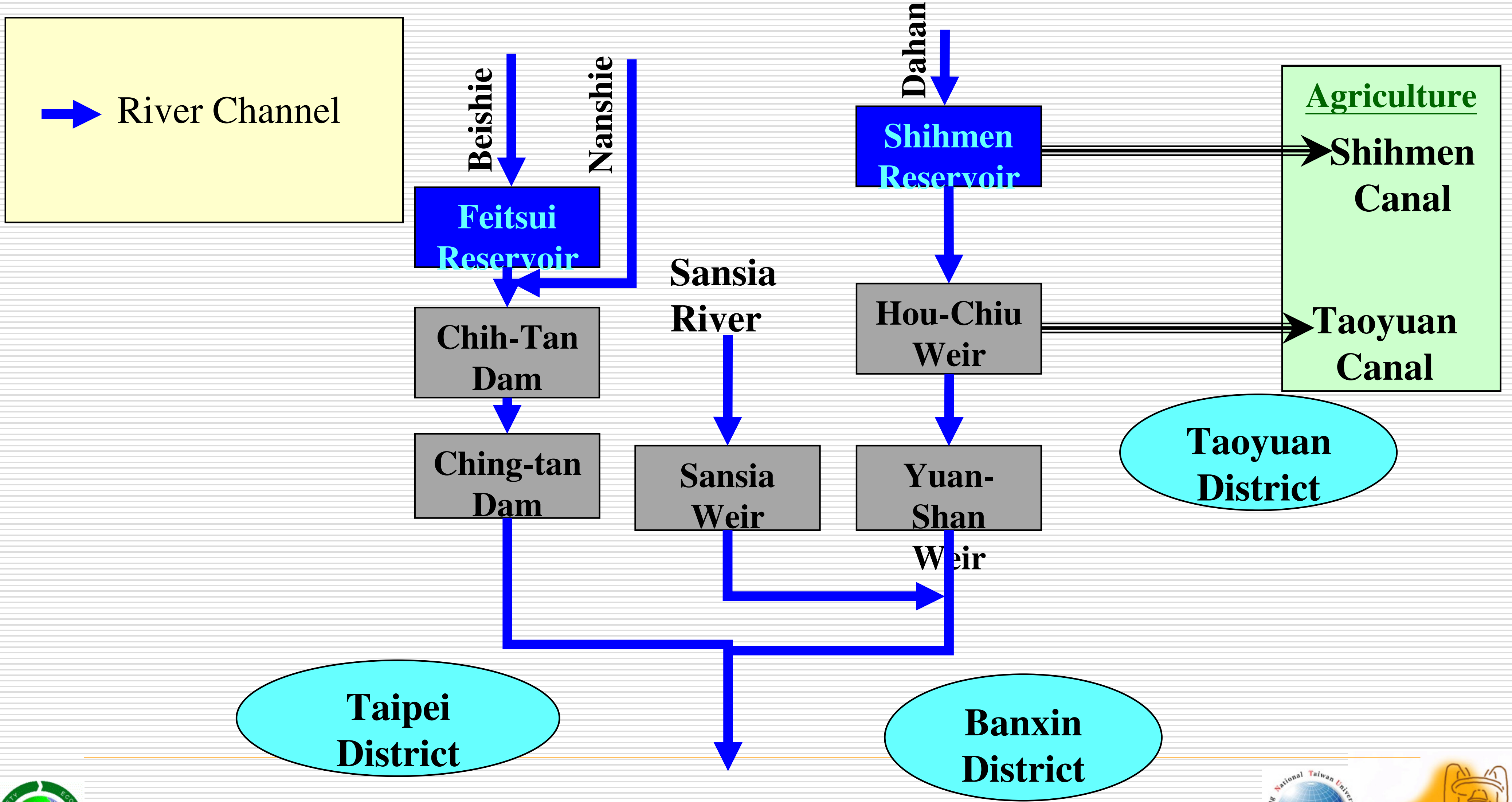
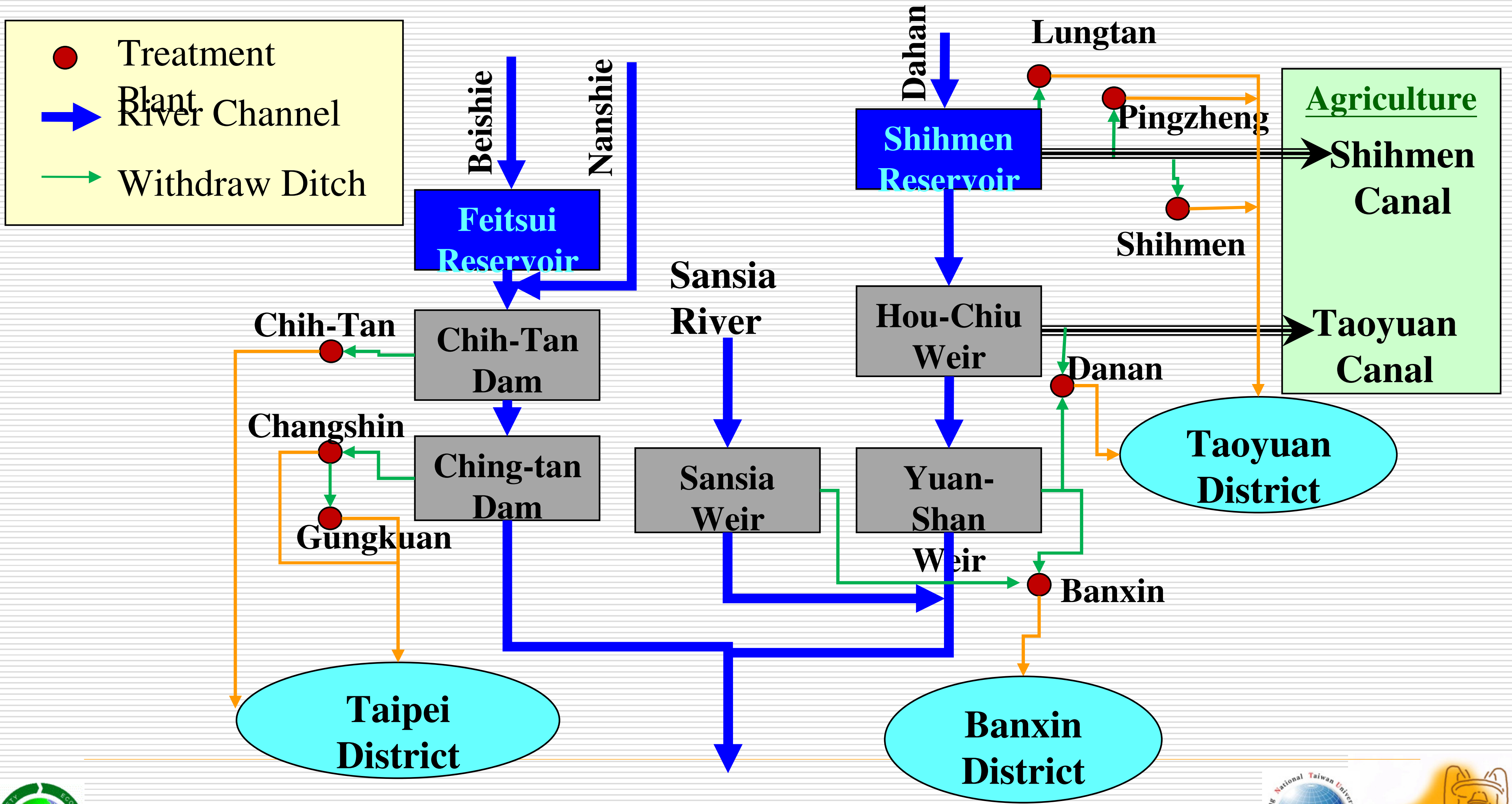
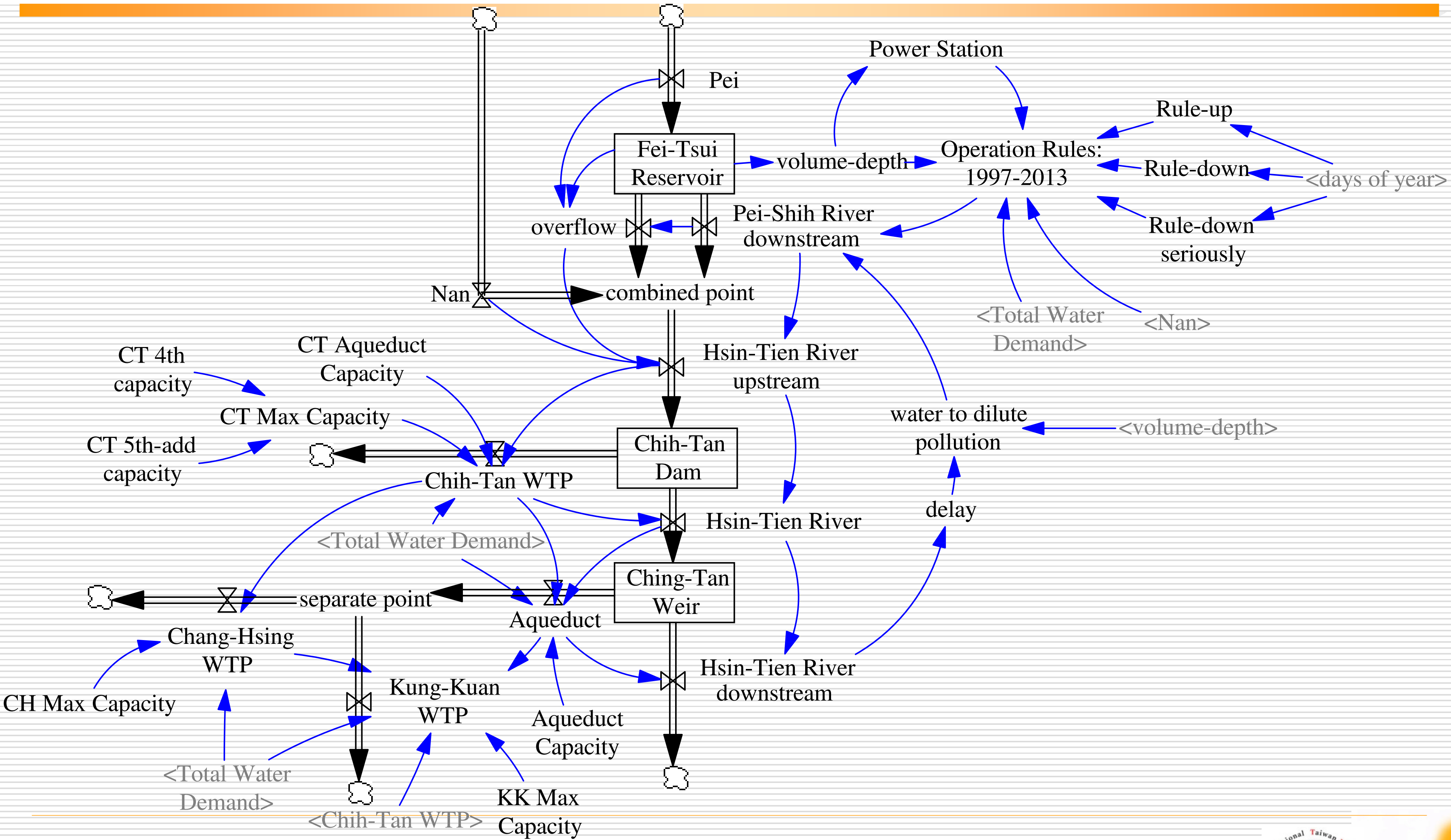
Water Supply System Dynamics Model
- the Sindian and Dahan River



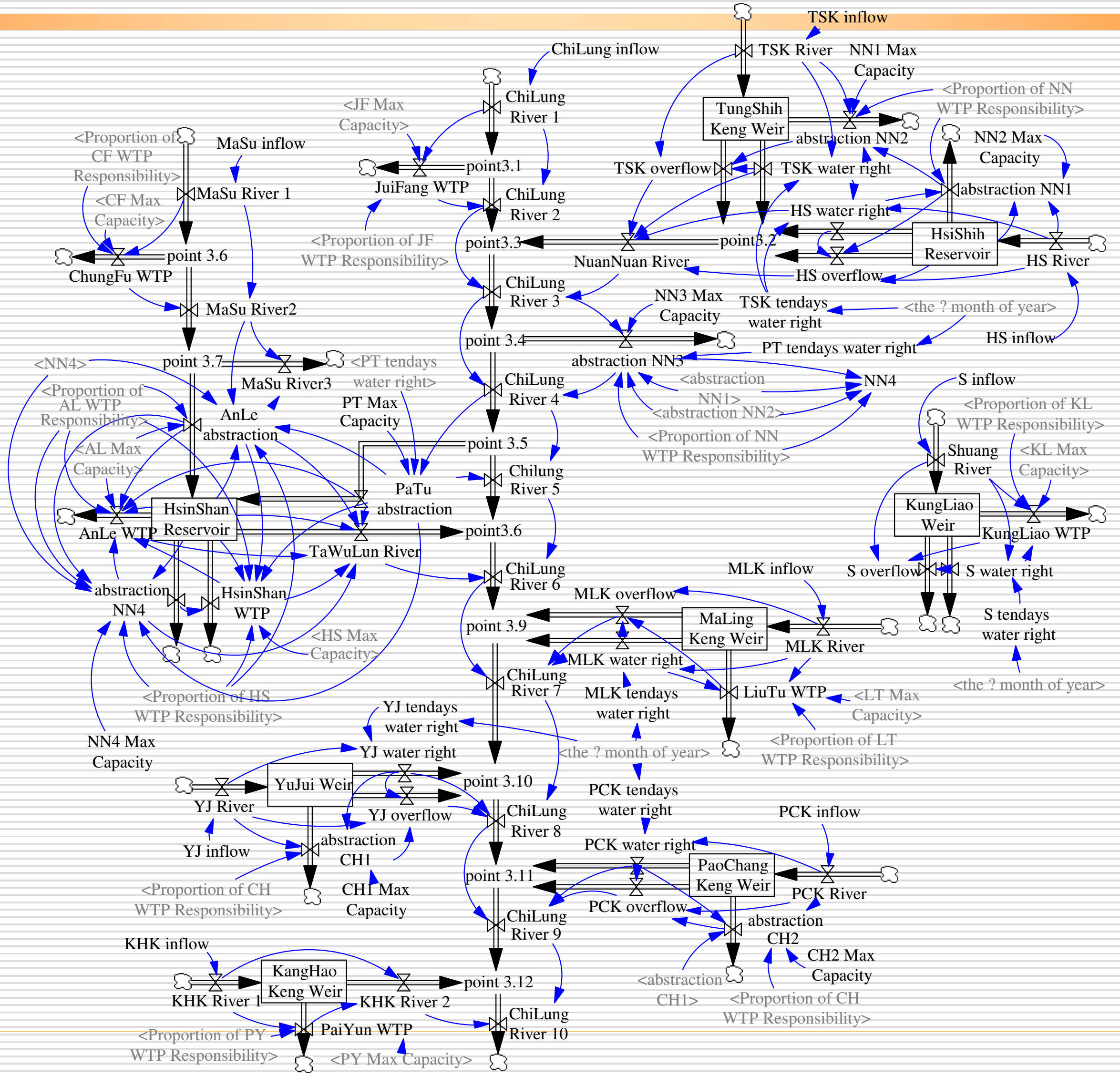
Water Supply System Dynamics Model
- the Sindian and Dahan River



The Sindian Water Supply System Dynamics Model



Keelung Water Supply System Dynamics Model

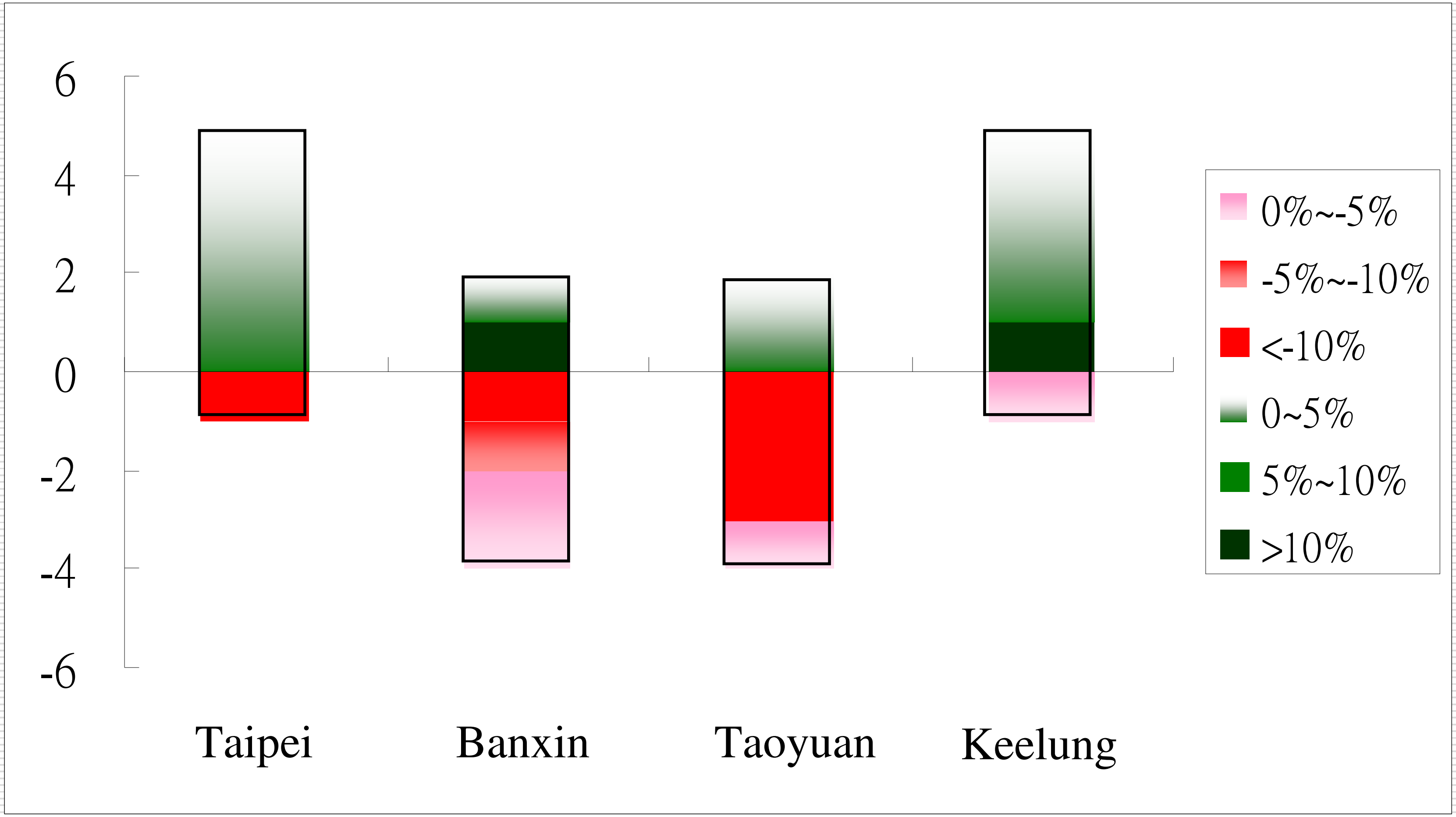


Current Water Supply Capability (1991~2001, unit: 10^4 CMD)

District	W/O Ban I Project		W/ Ban I Project	
	Demand	Supply	Demand	Supply
Taipei	220.9	282.0	220.9 52.6(支援板新)	348.7
Banxin	70.6	52.2	52.6(臺北支援) 18.0	69.3
Taoyuan	66.8	108.9	66.8	108.9
Keelung	22.9	36.3	22.9	36.3

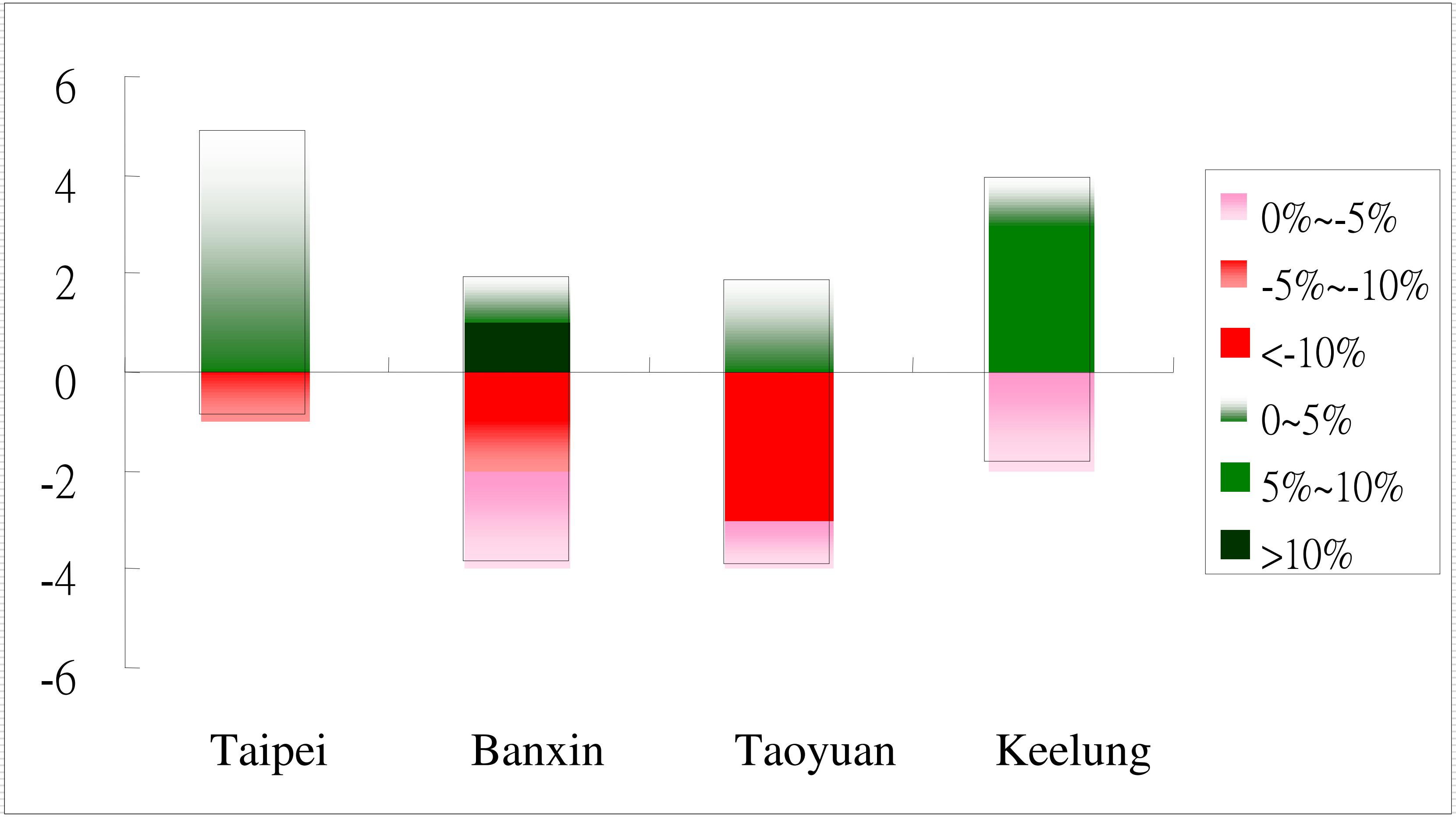
Trend of Water Supply Capacity

SRES-A2-Simple Downscaling



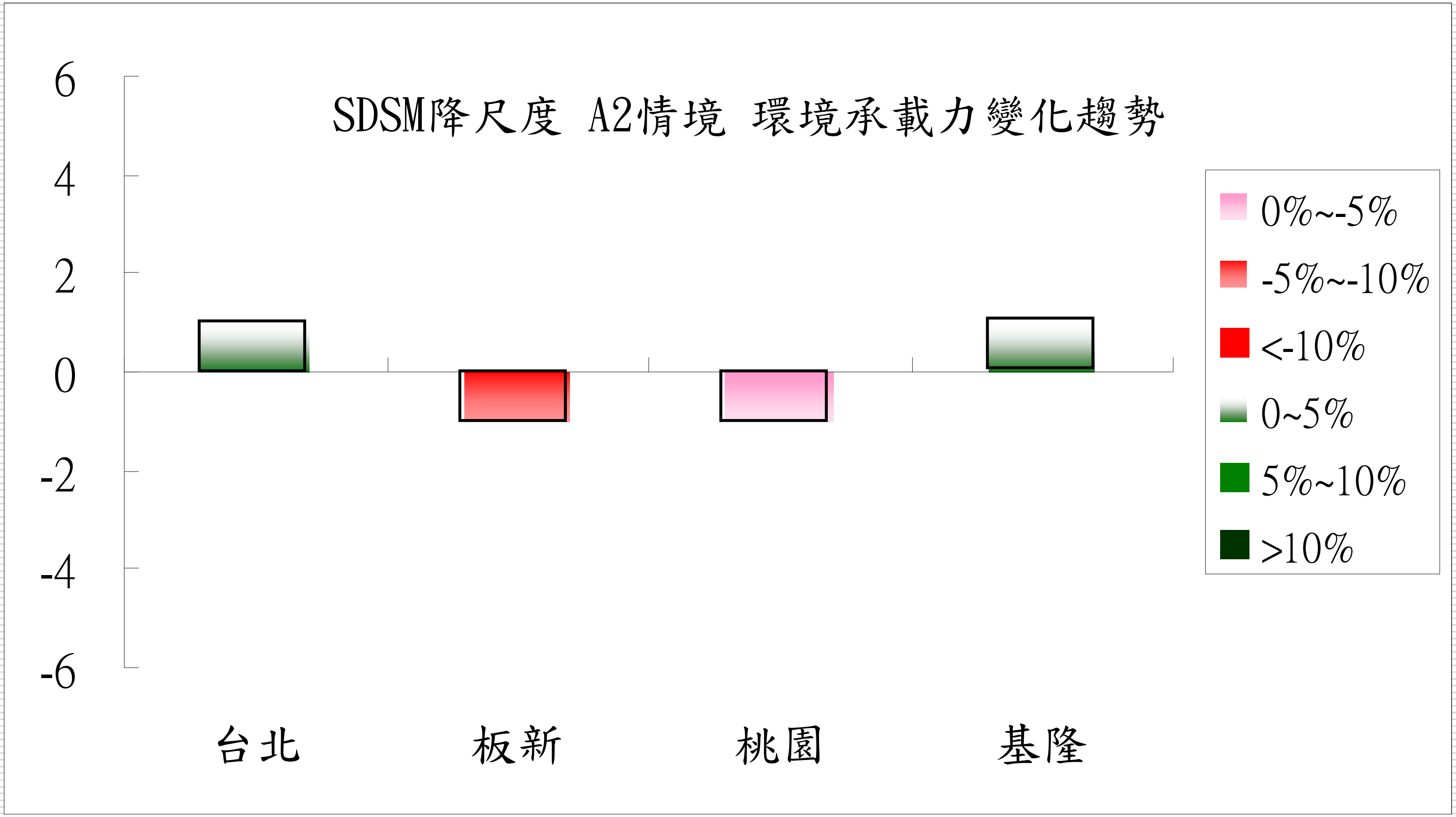
Trend of Water Supply Capacity

SRES-B2-Simple Downscaling



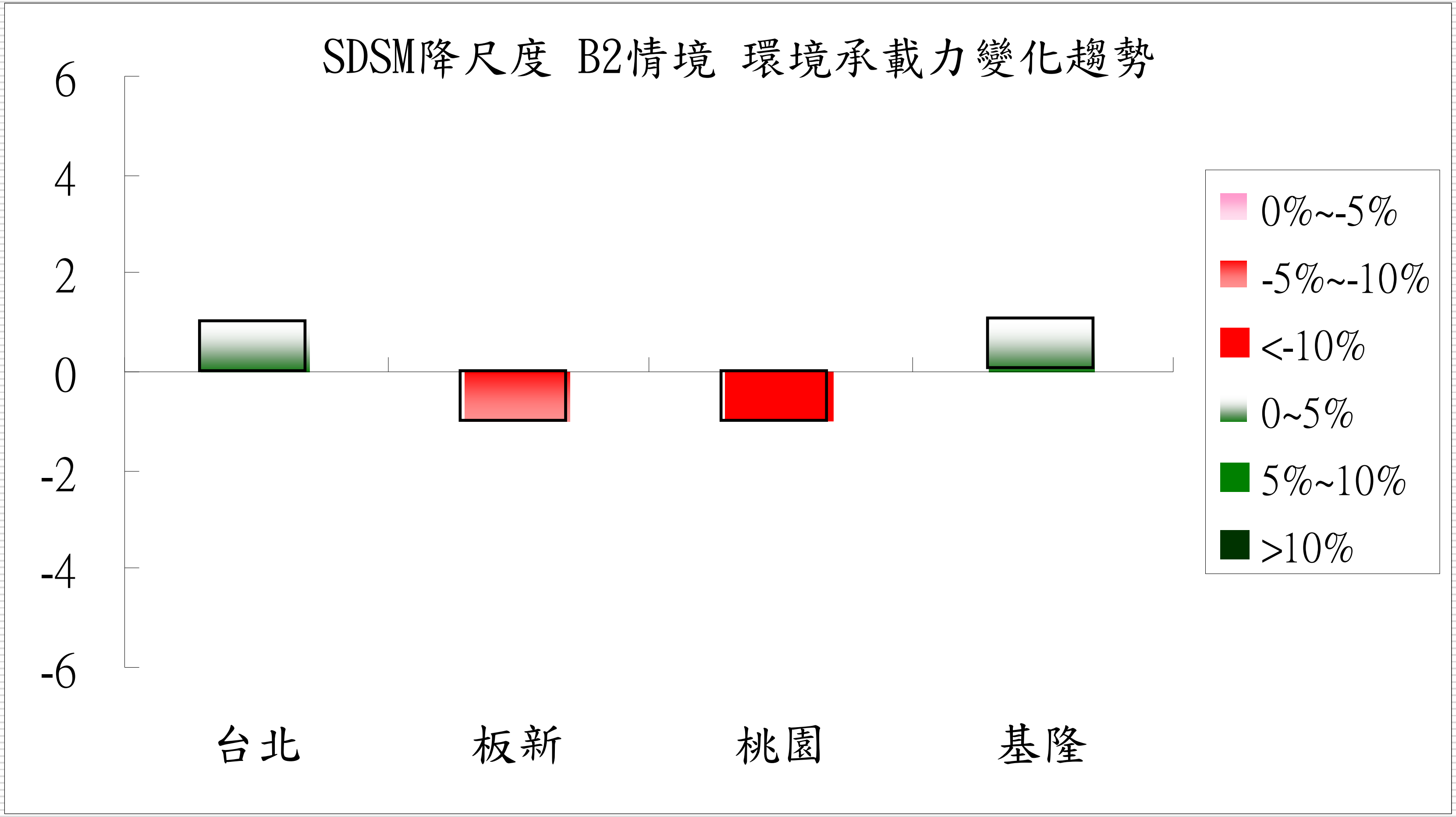
Trend of Water Supply Capacity

SRES-A2-SDSM Downscaling



Trend of Water Supply Capacity

SRES-B2-SDSM Downscaling



Ability to Meet Water Demand

- The Taipei District
  - Water supply for the Taipei is still sufficient for next 20~30 years, and it can deliver extra water to other districts.
- The Banxin District
  - The ability of water supply of the Banxin district may decrease due to reduced streamflows in dry periods. Water delivered from the Taipei district will be a very important strategy.

- The Taoyuan district
  - Water supply may decrease due to lower flows in dry periods.
  - Water demand increases significantly, which causes more water shortage.
  - Water demand management is very important. More water sources and new facility may also be required for the district.

- The Keelung District
  - Although the ability of water supply may increase in the Keelung district, significant increase of demand may still result in water deficit.
  - Currently, the utilization rate of the Keelung river is still low, more water treatment facility could be installed to increase water supply.

Adaptations

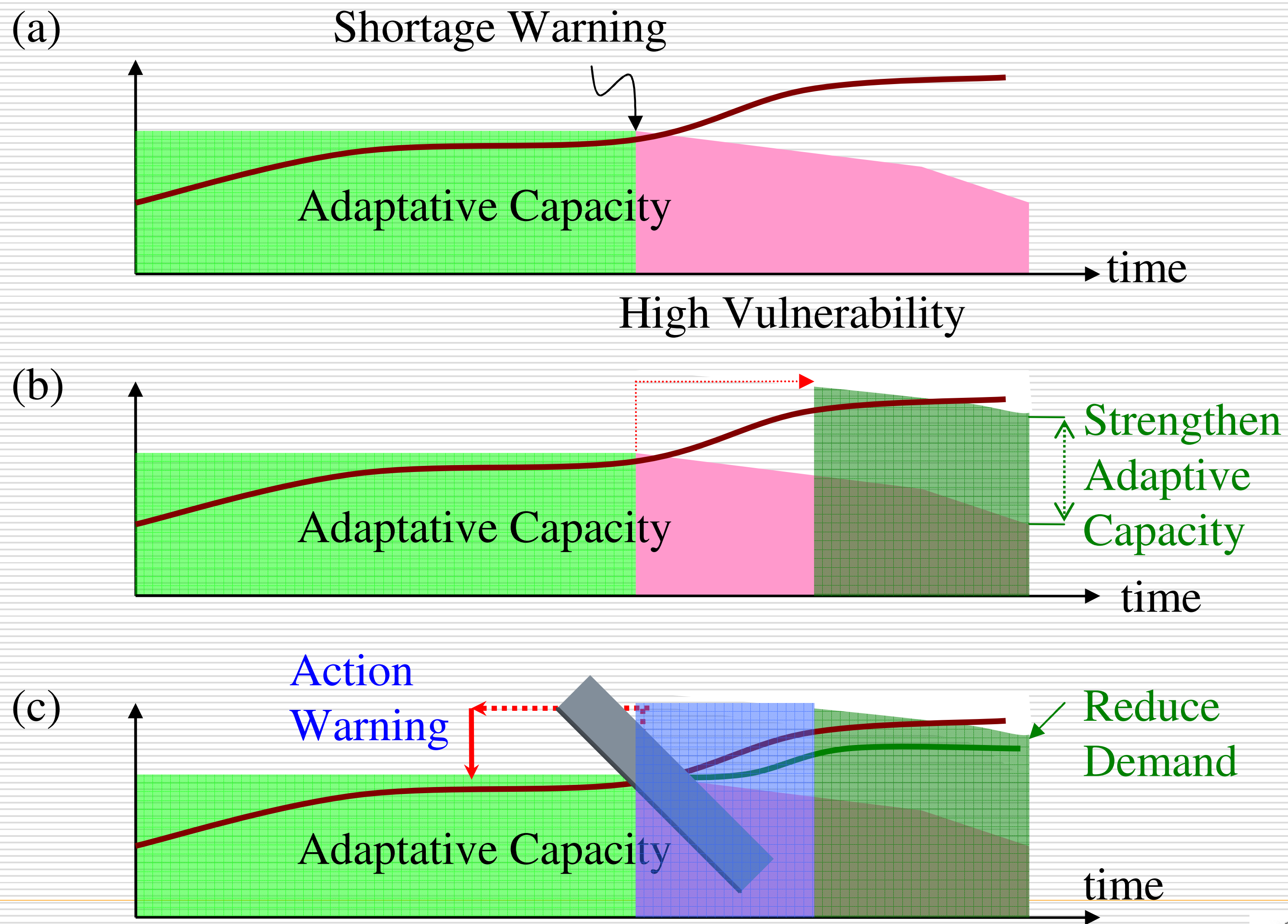
Principles to Strengthen Adaptive Strategies

- Identify the most vulnerable components and their corresponding strategies.
  - Insufficient water resources?
  - Less flexible water management plan?
  - Too many water demands?
- Develop an early warning systems to trigger actions.

Key points on Strengthening Adaptive Capacity of Water Supply Systems

- Demand Management
  - Water Saving
  - Land Planning
- Water Management Ability
  - Connecting different systems
  - Natural conservation
- New Water Sources & Facility
  - Groundwater
  - Rainfall Harvesting
  - New Treatment Facility

Early Warning Systems to Strengthen Adaptive Capacity



Early Warning and Risk Management Systems

Systems	Time Scale	Responses
Real time	Hourly, Daily	Operational Measures
Seasonal	Season, Half year	Management
Near-term	Several years	Management
Long-term	Ten years	Planning Management

Long-term Planning Adaptations to Changing Climate

Ranking Adaptation Strategies

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Decision making on Adaptation Actions

- Taking actions depends on several factors, including

  (1)Time left to take action,

  (2)Uncertainty,

  (3)Effectiveness in reducing risk & vulnerability,

  (4)Costs (regret or non-regret)

  Action = F(T, U, E, C)

- Ranking Tool: Analytic Hierarchy Process

Example of AHP Analysis

GOAL

Ranking Adaptive Strategies in Taoyuan

Principle

- Cost-Benefit
- Time
- Effectiveness
- Uncertainty
- No-Regret
- Justice
- Vulnerability
- Reversable

Alternative

- Ta-Han River Southern Re-allocation (SRA)
- Lung-Tan Water Treatment Plant Expansion(WTPE)
- Desalination Plant (DP)

Results

Weightings of all Principles

Cost-Benefit	Time	Effectiveness	Uncertainty
0.374	0.208	0.296	0.122

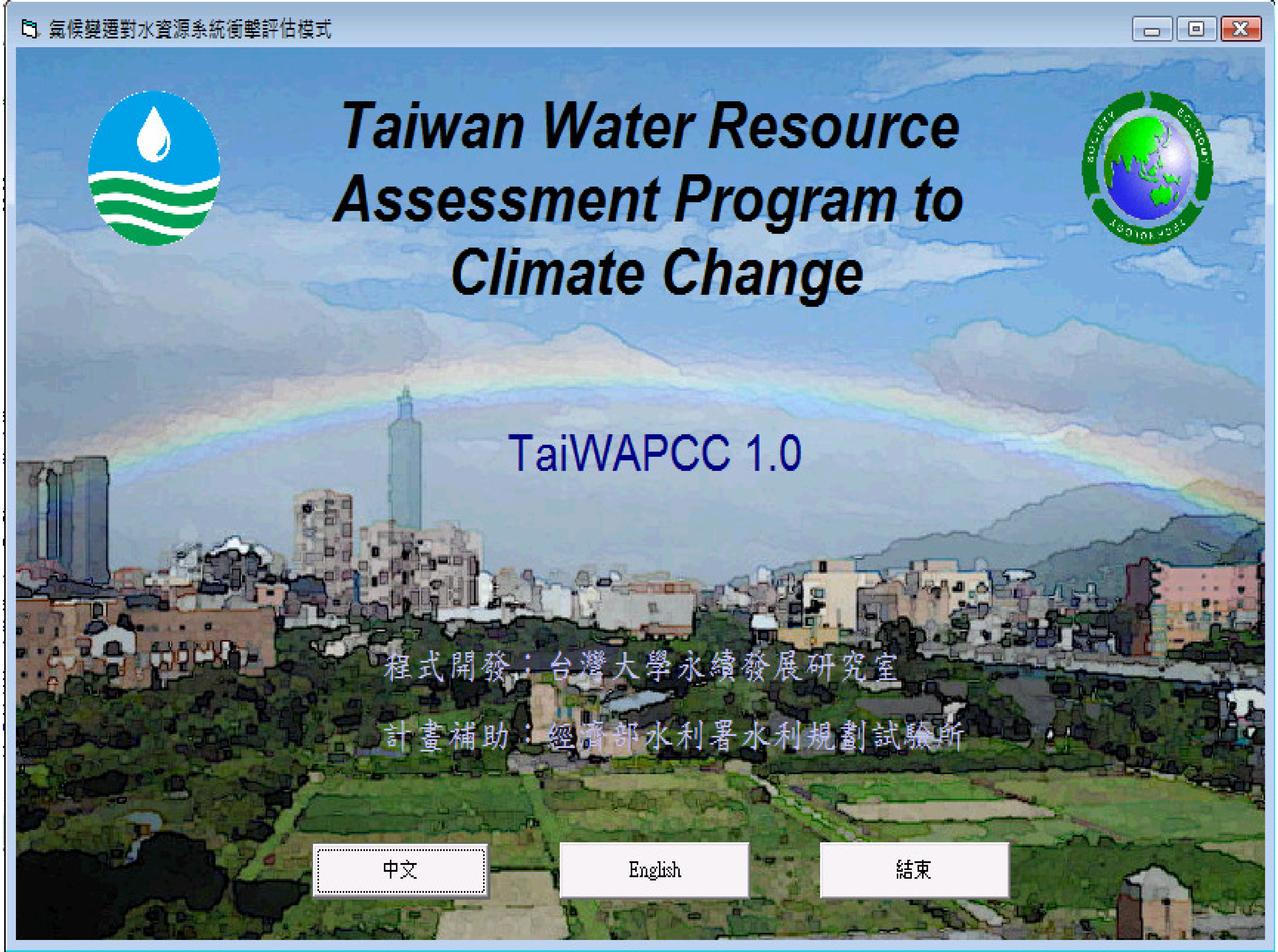
Weightings of all Alternatives

	SRA	WTPE	DP
Cost-Benefit	0.367	0.572	0.061
Time	0.214	0.393	0.393
Effectiveness	0.293	0.266	0.442
Uncertainty	0.379	0.152	0.469

Ranking

SRA	WTPE	DP
0.315	0.393	0.292

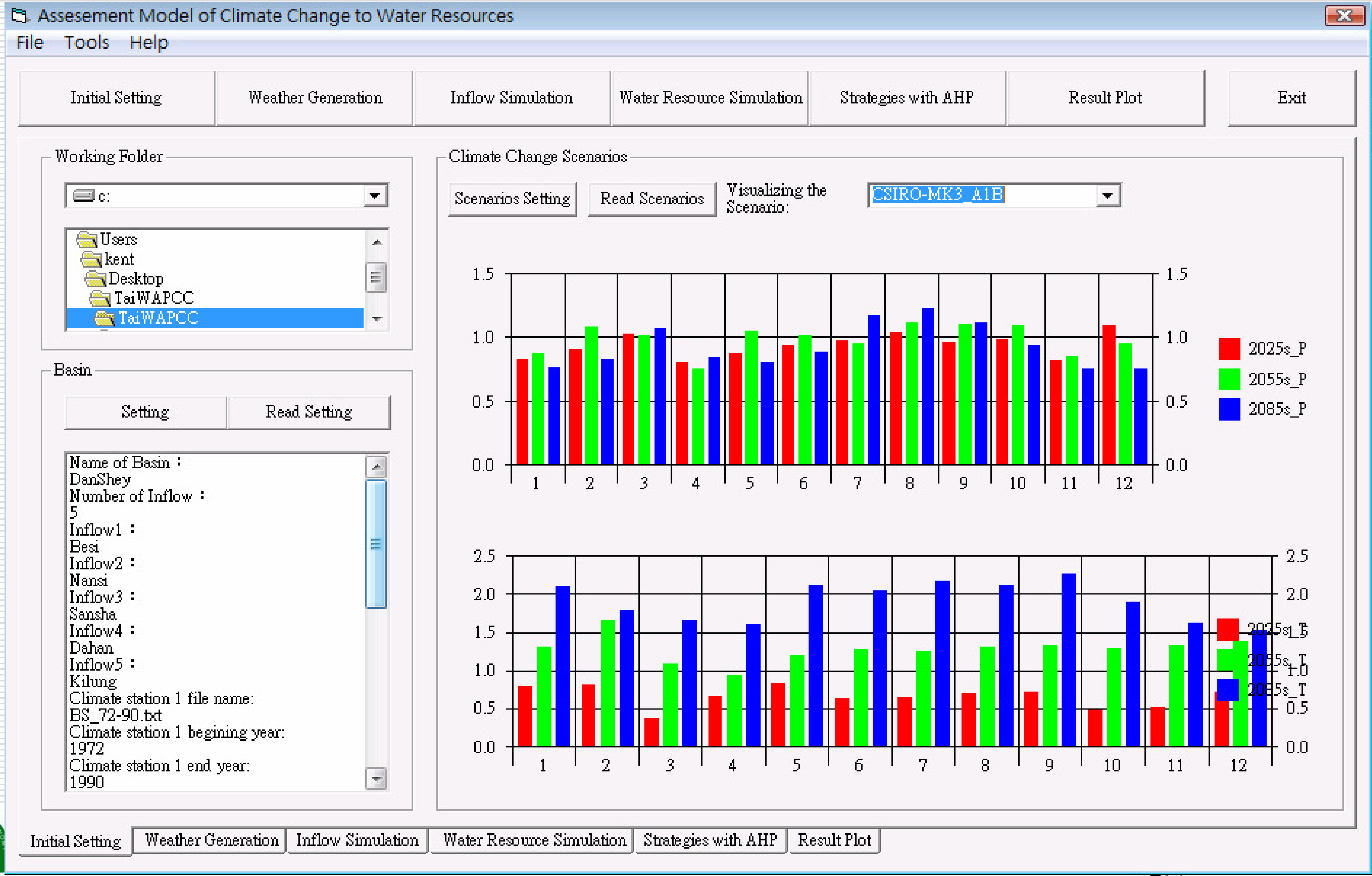
Lung-Tan Water Treatment Plant Expansion (WTPE)
is the best of the three assessed Adaptative strategies in Taoyuan.


氣候變遷對水資源系統衝擊評估模式
Taiwan Water Resource Assessment Program to Climate Change
TaiWAPCC 1.0
程式開發：台灣大學永續發展研究室
計畫補助：經濟部水利署水利規劃試驗所
中文
English
結束

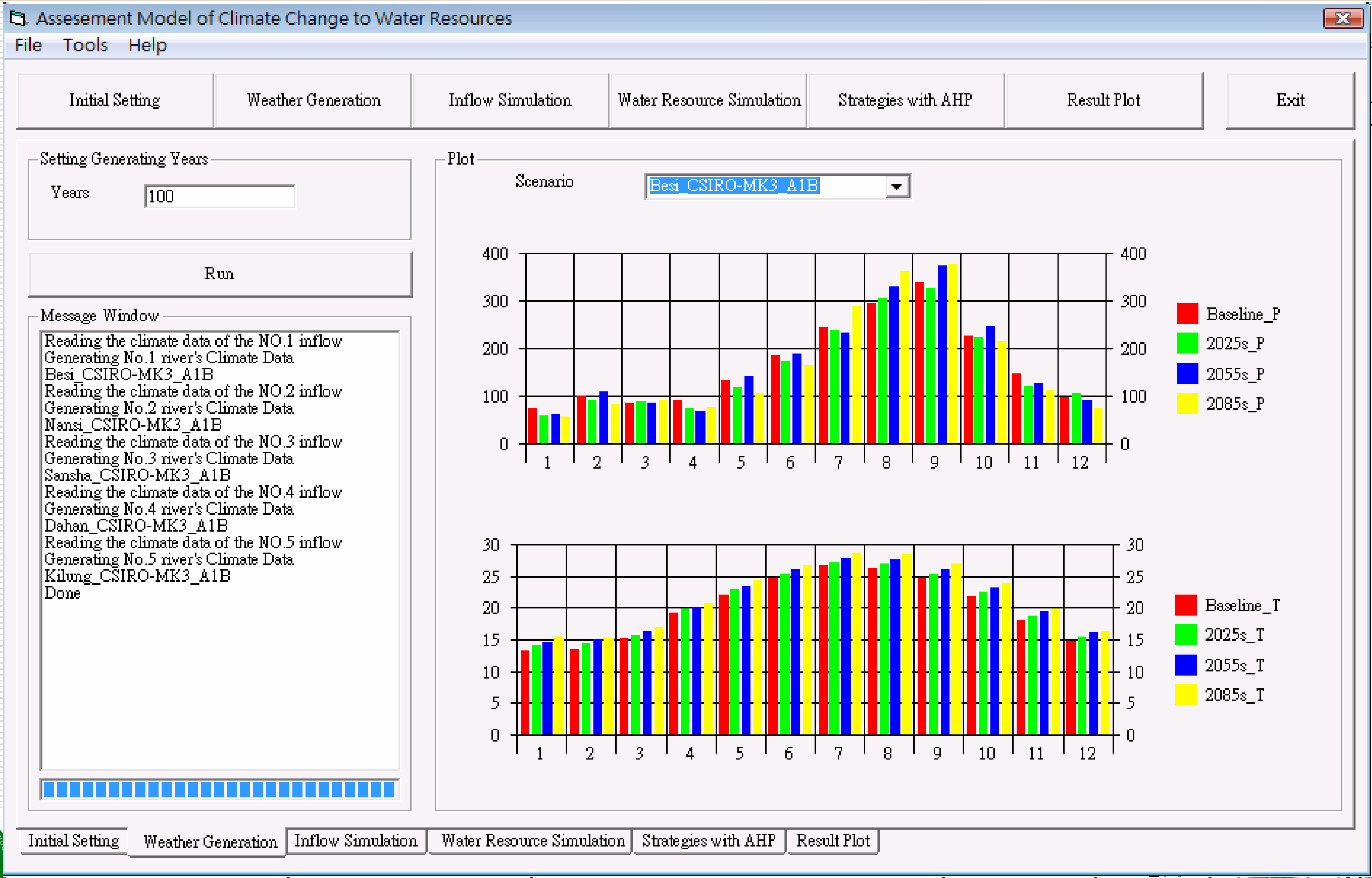
Functions

- Analyzing historical hydrological data
- Preparing climate scenarios (10 GCMs and 3 SRES scenarios)
- Generate daily weather data
- Simulate impacts on stream flows (the HBV and GWLF models)
- Simulate Impacts on water supply systems (Link to a pre-developed system dynamics model, VENSIM)
- Rank adaptation strategies (Analytic Hierarchy Process)

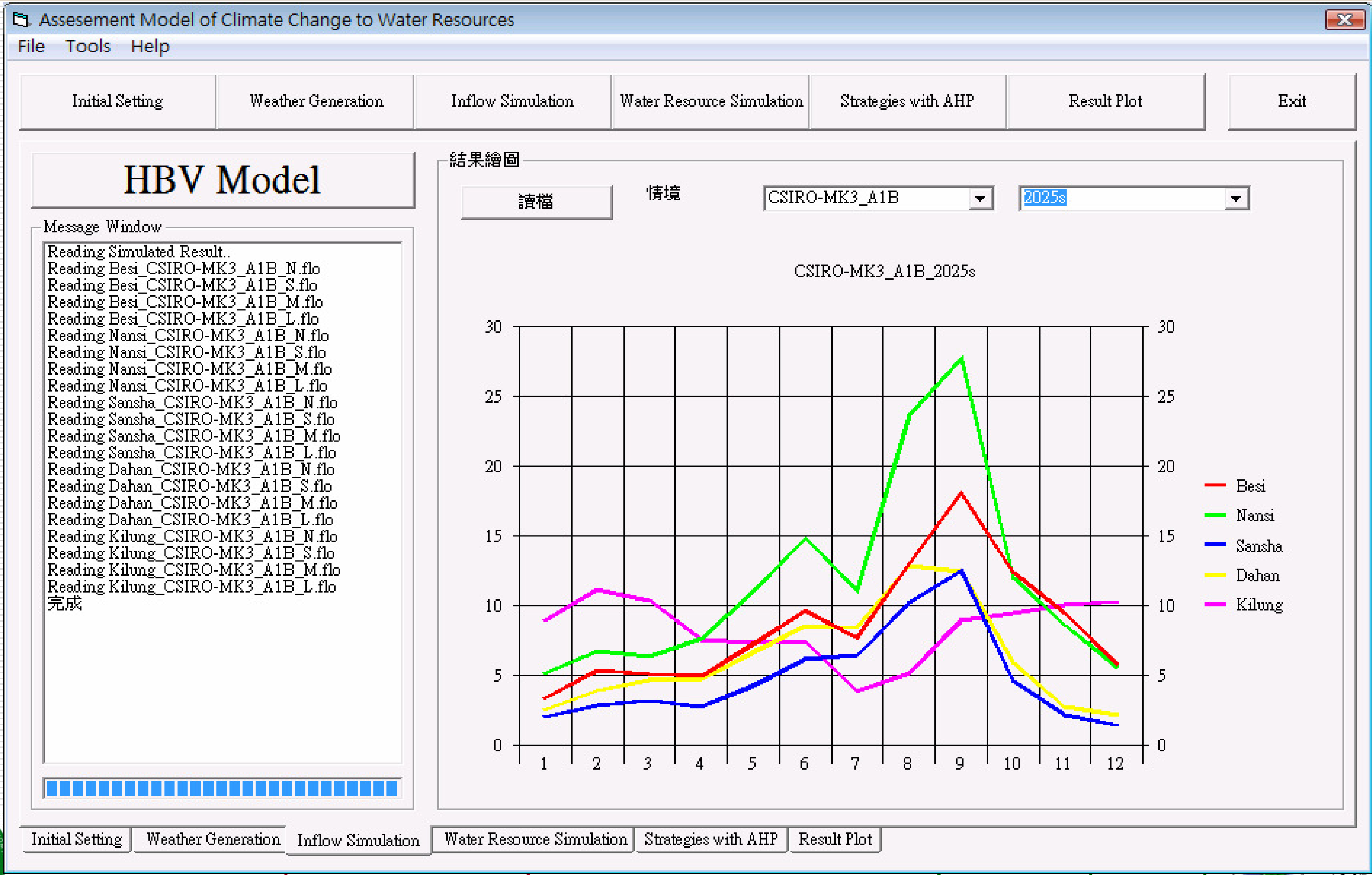
Initial Setting



Weather Generator



HBV MODEL


Assesement Model of Climate Change to Water Resources
File Tools Help
Initial Setting
Weather Generation
Inflow Simulation
Water Resource Simulation
Strategies with AHP
Result Plot
Exit
HBV Model
Message Window
Reading Simulated Result..
Reading Besi_CSIRO-MK3_A1B_N.flo
Reading Besi_CSIRO-MK3_A1B_S.flo
Reading Besi_CSIRO-MK3_A1B_M.flo
Reading Besi_CSIRO-MK3_A1B_L.flo
Reading Nansi_CSIRO-MK3_A1B_N.flo
Reading Nansi_CSIRO-MK3_A1B_S.flo
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Reading Nansi_CSIRO-MK3_A1B_L.flo
Reading Sansha_CSIRO-MK3_A1B_N.flo
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Reading Dahan_CSIRO-MK3_A1B_L.flo
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Reading Kilung_CSIRO-MK3_A1B_M.flo
Reading Kilung_CSIRO-MK3_A1B_L.flo
完成
結果繪圖
讀檔
情境
CSIRO-MK3_A1B
2025s
CSIRO-MK3_A1B_2025s
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15
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1 2 3 4 5 6 7 8 9 10 11 12
Besi
Nansi
Sansha
Dahan
Kilung
Initial Setting
Weather Generation
Inflow Simulation
Water Resource Simulation
Strategies with AHP
Result Plot

More functions will be added

- Better statistical downscaling methods
- Better impact simulation on water resource systems
  - Agricultural Water Demands
  - Groundwater
  - Rainfall Harvesting Systems
  - Water Quality
- Better water resources management tools
  - Conjunction uses of surface and ground water
  - Modification on reservoir operational rules

Seasonal Forecasts and Responses to Climate Variability

1. Forecasts on water demand and supply
2. More flexible management strategies

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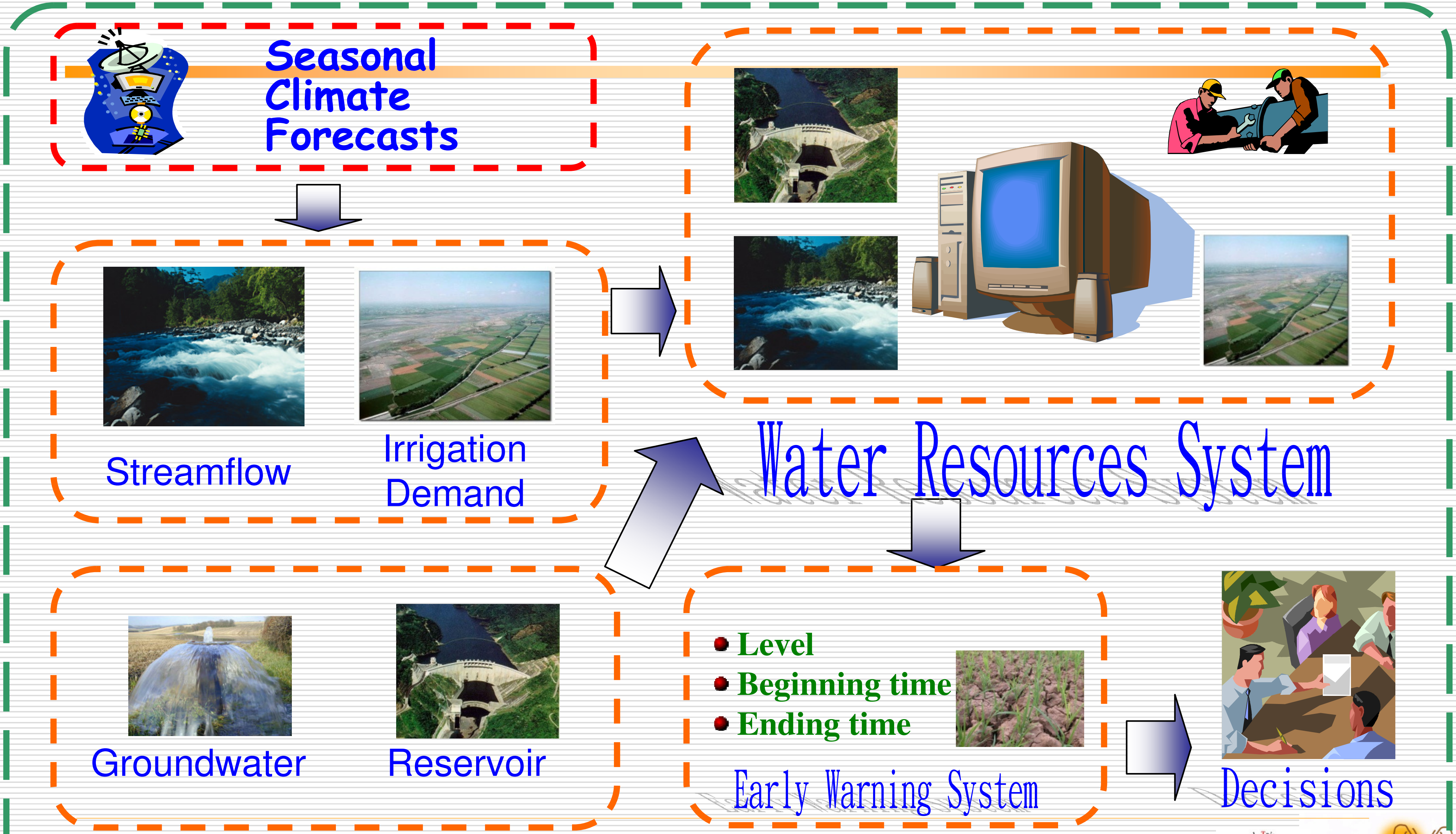
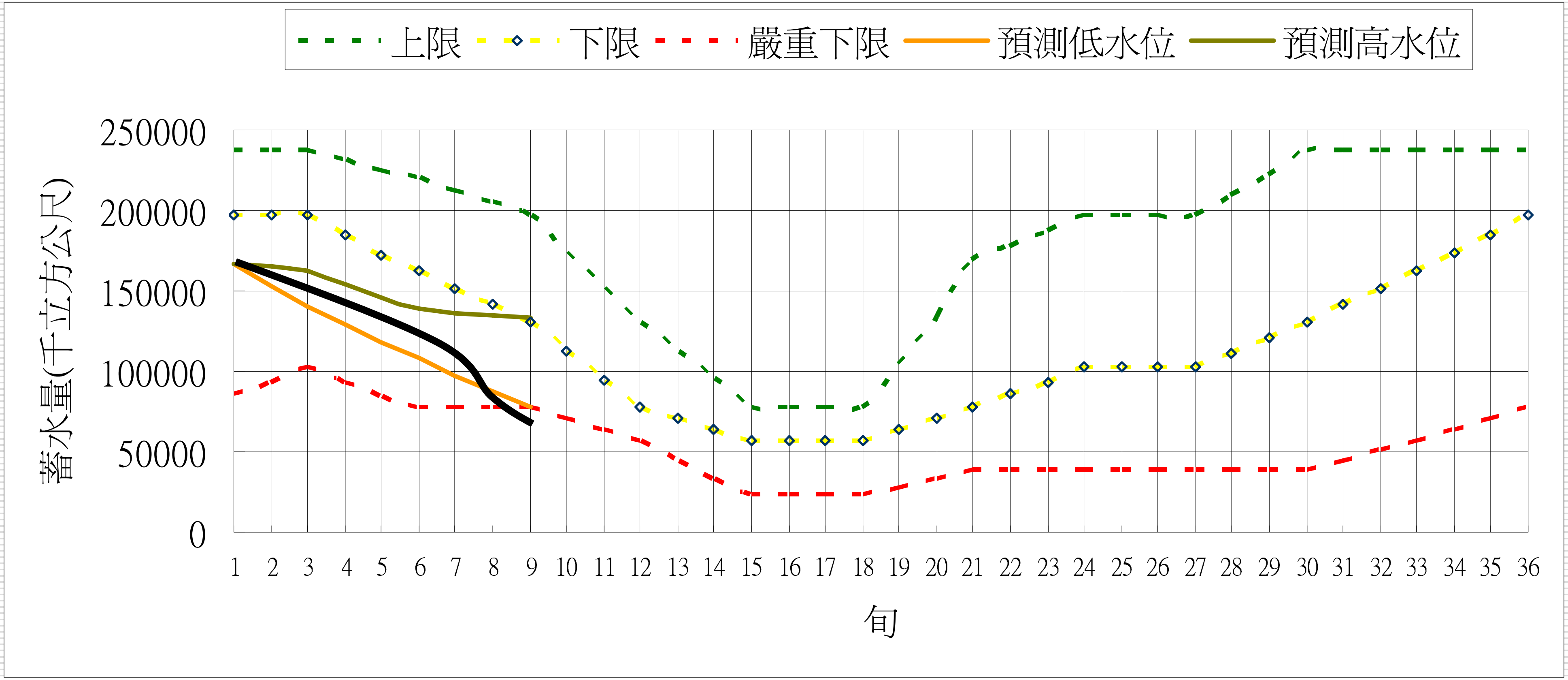
Seasonal Drought Early Warning and Risk Management System

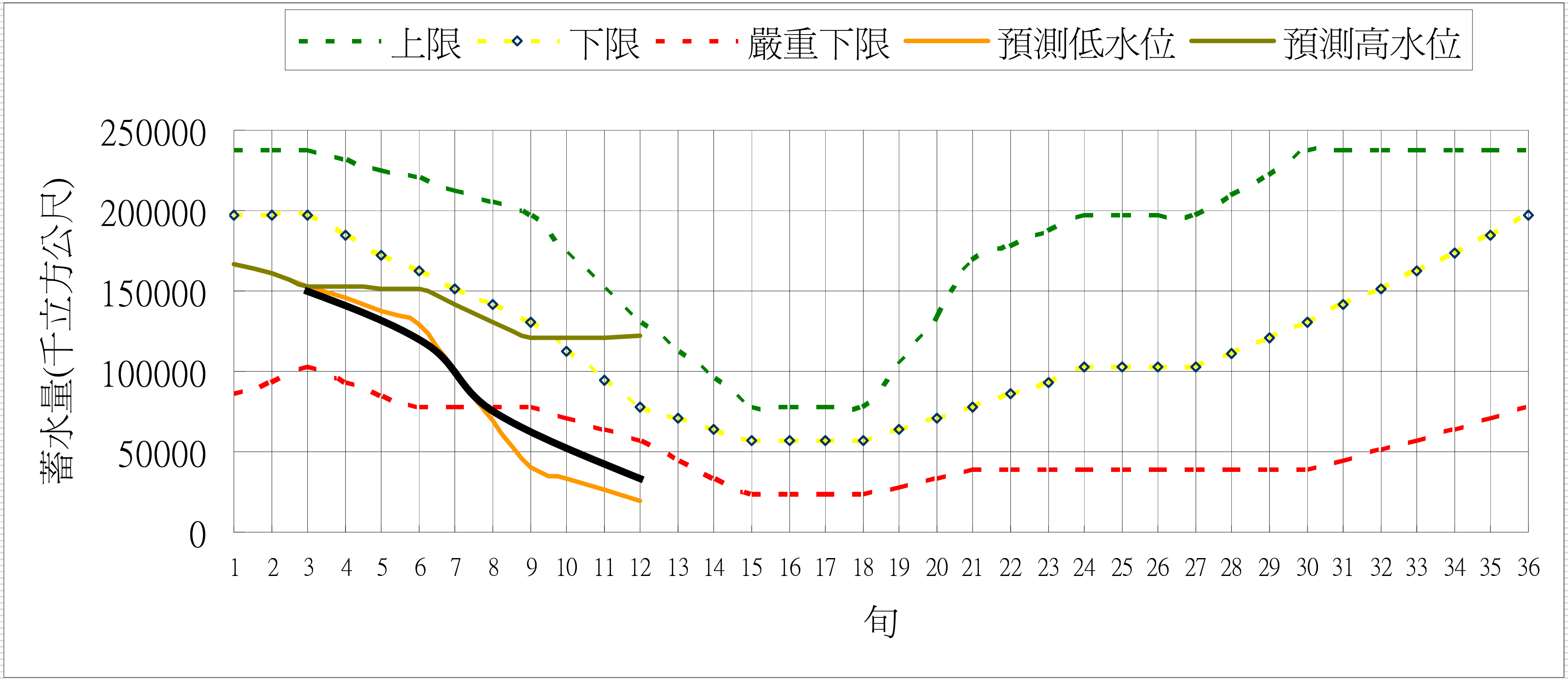


Seasonal Storage Forecasts
- January, February, March (JFM, 2002)

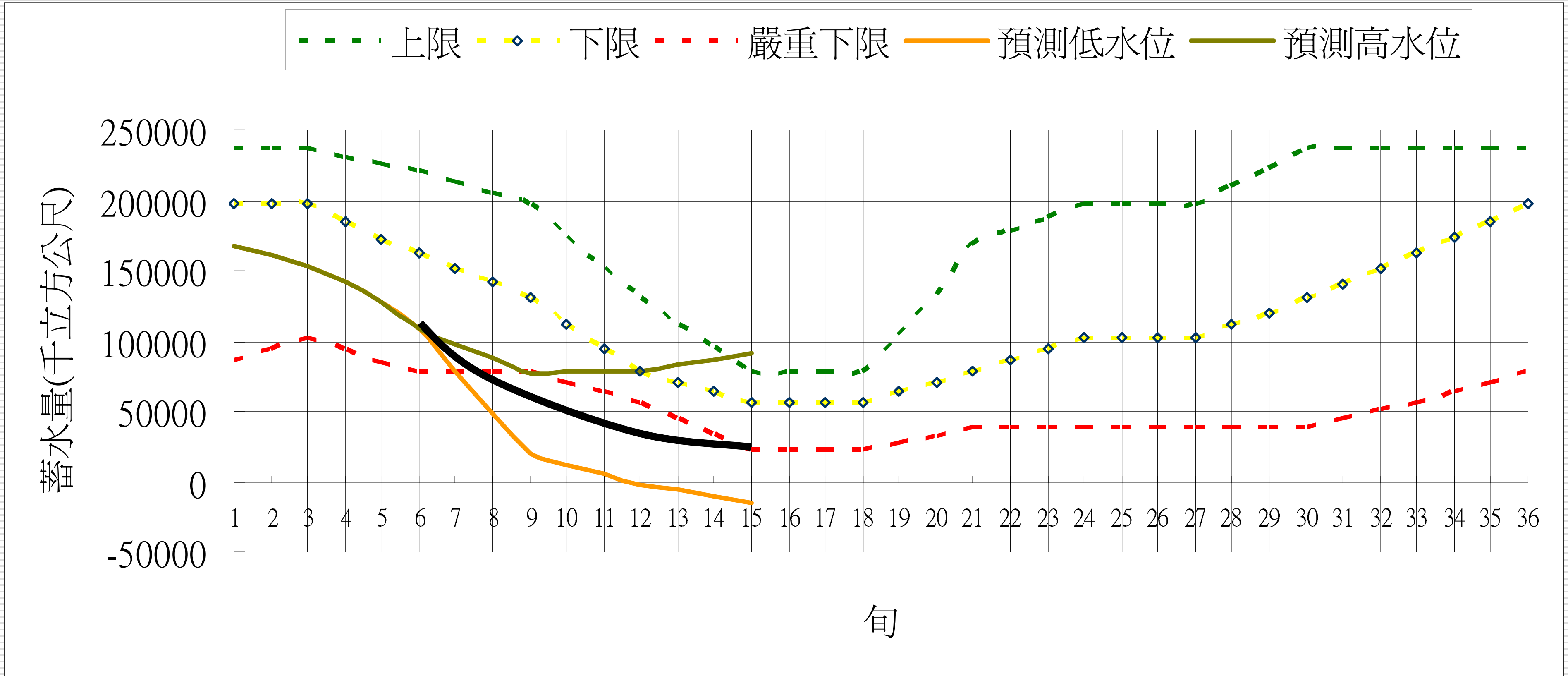


Seasonal Storage Forecasts

- February, March, April (FMA , 2002)



Seasonal Storage Forecasts
- March, April, May (MAM, 2002)



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http://sdl.bse.ntu.edu.tw/water01/2006_01.htm

國立台灣大學
生物環境系統工程學系 永續發展研究室

Sustainable Development Laboratory Department of Bioenvironmental Systems Engineering N.T.U.

- 關於我們
- 教學課程
- 研究領域
- 研究成果
- 水資源預測
- Flash教學
- 研究室成員
- 下載專區
- 資訊交流
- 討論園地

水資源預測

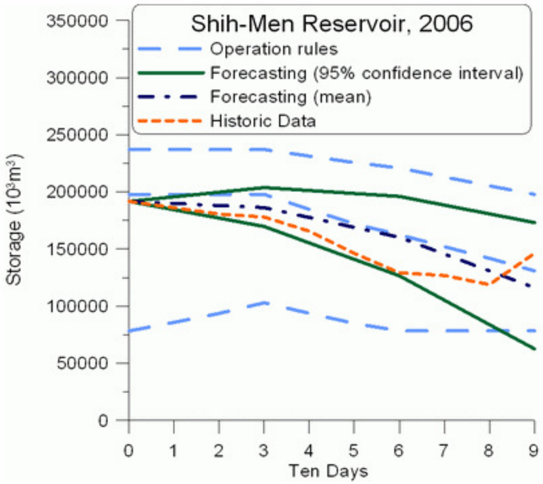
利用中央氣象局長期氣候預報資料進行水庫蓄水量預報

石門水庫過去蓄水量預報結果

回前頁

年份	一月	二月	三月	四月	五月	六月	七月	八月	九月	十月	十一月	十二月
2006	CWB	CWB	CWB	CWB	CWB	CWB	CWB	CWB	CWB	CWB	CWB	CWB
2007	CWB	CWB	CWB									

2006年1月 (一月~三月預報, 亦即第1旬~第9旬預報)



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完成

Benefits of Applying Seasonal Information

Year	Actual		Estimate			Benefits (100 Million)
	Stop Farming Area (ha)	Money paid to Farmers (100 Million)	Stop Farming Area (ha)		Money paid to Farmers (100 Million)	
2002	10,439(3月休耕) 4,700(5月休耕)	11.8 (11.3)	10,556.4		7.7	+ 4.1(+3.6)
2003	24,749	14.9 (10.6)	case 1	0	0	+14.9(+10.6)
			case 2	7037.6	4.2	+10.7(+6.4)
2004	36,730	22.0 (27.9)	21,112.8		12.7	+ 9.3(+15.2)
2006	24,597	16.6 (13.8)	0		0	+16.6(+13.8)
B/C = NT$4,960,000,000/NT$285,000 = 17,403					Total：	+55.6(+49.6)

Final Remarks

- Sustainable uses of water resources is our goal. The abilities to evaluate climate change and to strengthen adaptive capacity are very important to reach the goal.
- Uncertainty is the major constraint on taking actions. Early warning and risk management systems are very important for adapting to future climate.

Thanks for Listening!

All Questions are Welcomed!

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