Strengthening Water Supply System Adaptive Capacity

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- Recent Climate-Induced Disasters
- Future Possible Climate Change Impacts
  - Water Supply Carrying Capacity of the GaoPing Watershed
- Strengthening the Adaptive Capacity of Water Supply Systems
- Final Remarks

Recent Climate-Induced Disasters

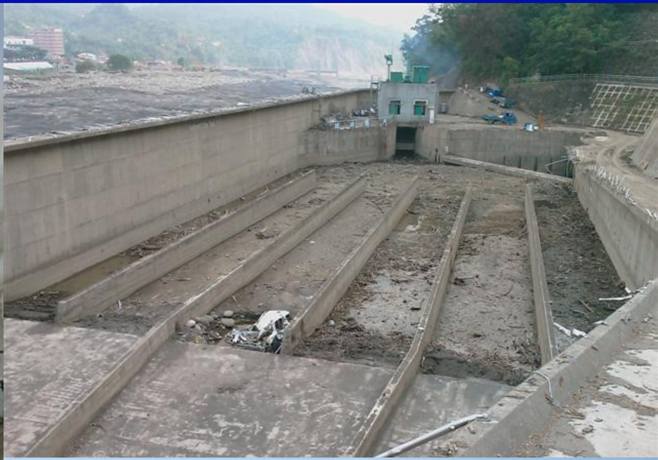
More Frequent and Intensive Extreme Events!

Flooding in Taipei
Sept. 17, 2001
Return Period of Rainfall more than 150 years

Drought in Taipei Area
Spring, 2002

Shihmen Reservoir

Typhoon Morakot
August 7-8, 2009



Typhoon Morakot

- The Typhoon Morako intruded Taiwan during 7th to 8th in 2009 and brought about 2,700 mm total rainfall.
  - The annual rainfall in Taiwan is about 2,550mm.

http://www.boston.com/bigpicture/2009/08/typhoon_morakot.htm

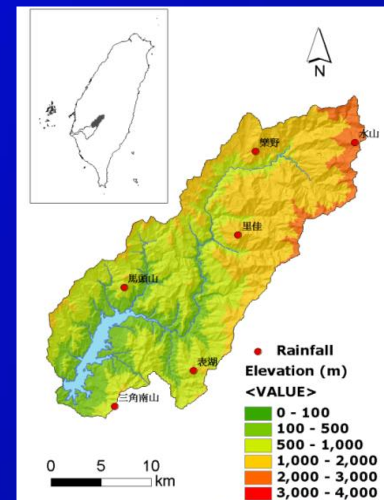
http://img200.imageshack.us/img200/961/shiaolinaftermorakot.jpg

ChiaXian Weir 甲仙攔河堰

(2009／8／18, ten days after typhoon)

Zengwen Reservoir

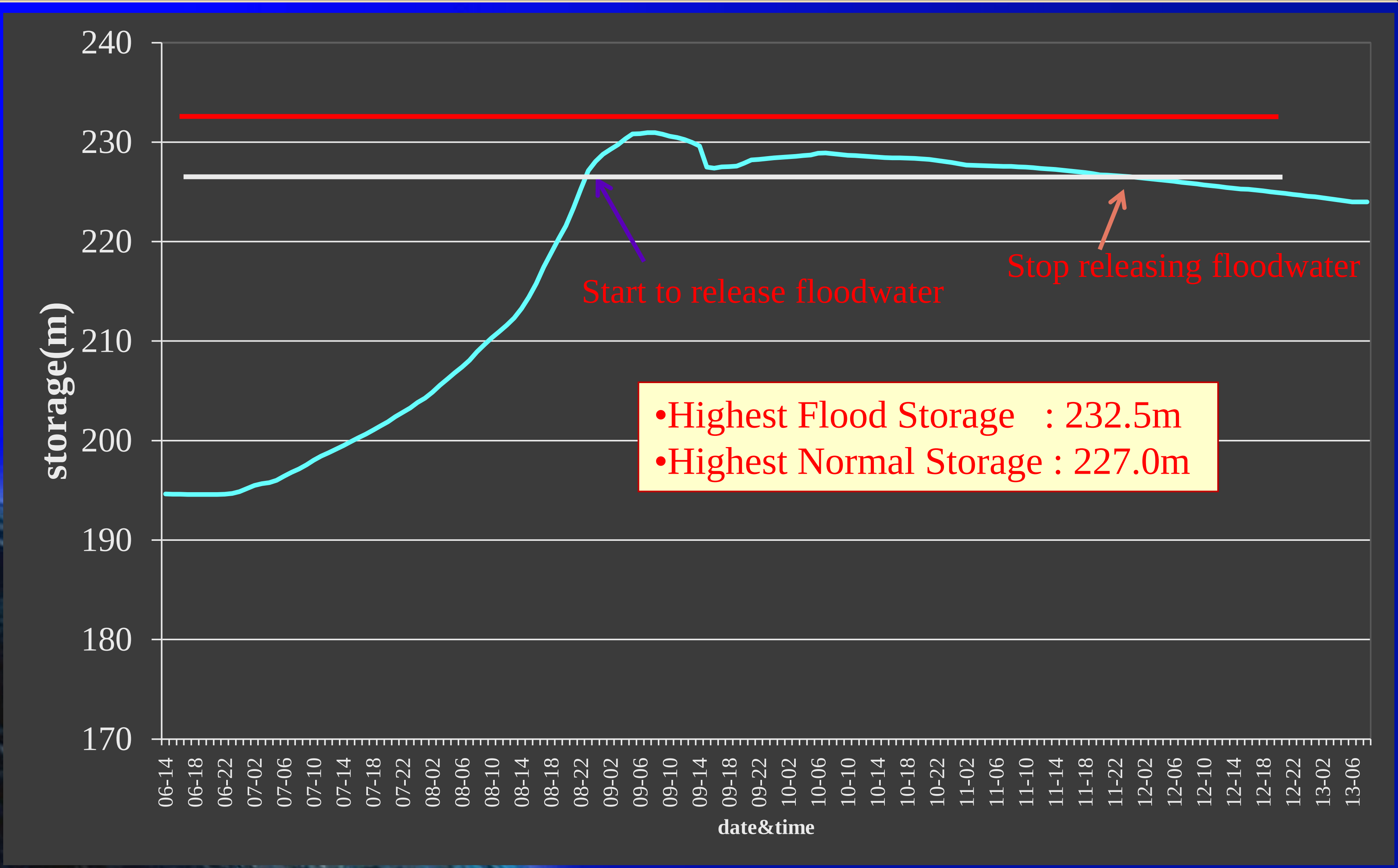
Before 2009/8/8

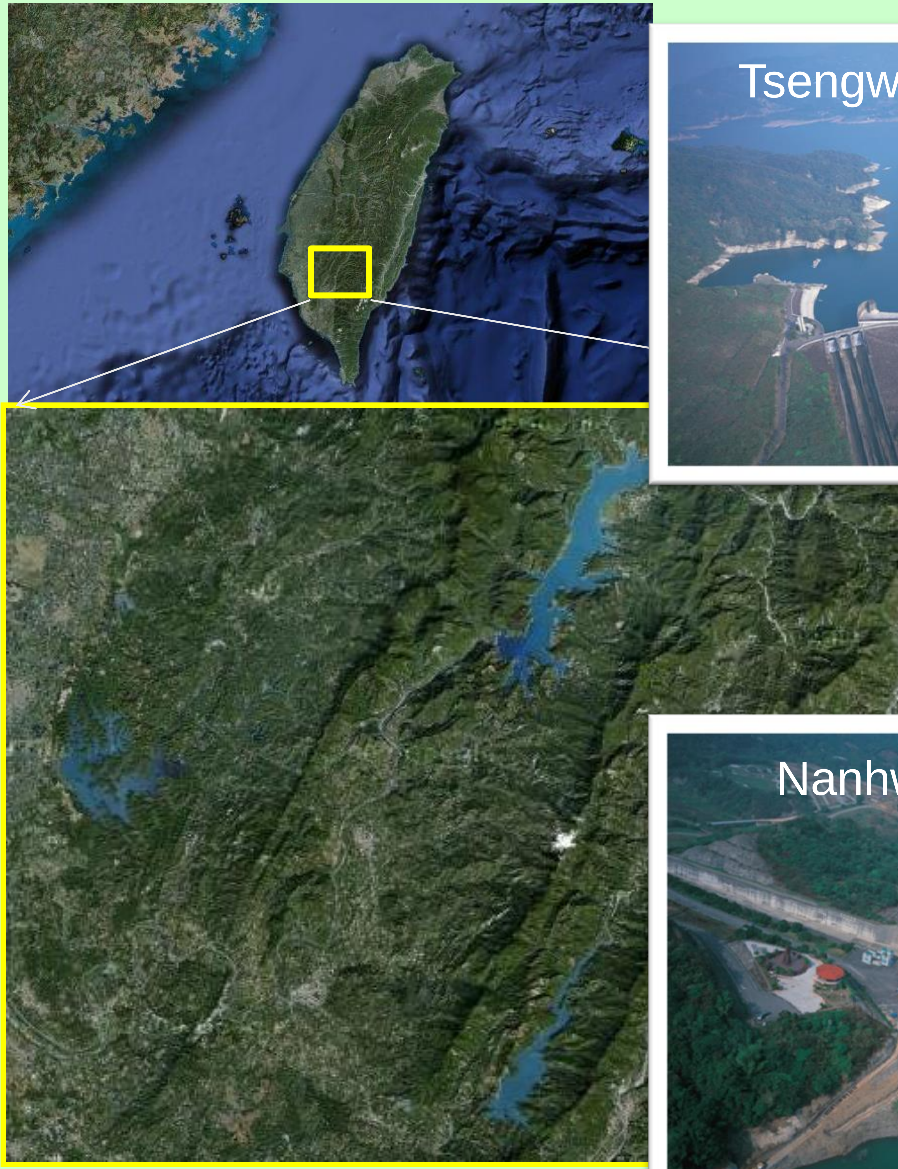


After 2009/8/8

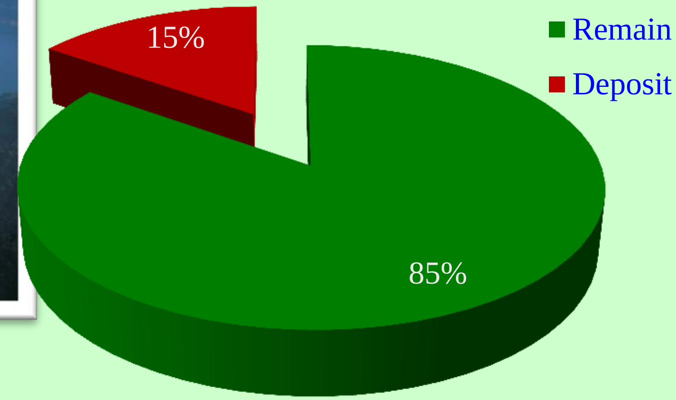
- Zengwen Reservoir
  - the most important reservoir in southern Taiwan
  - Watershed is 481 km^2
  - Annual rainfall is 2,897mm
  - Effective storage is 590 million tons.

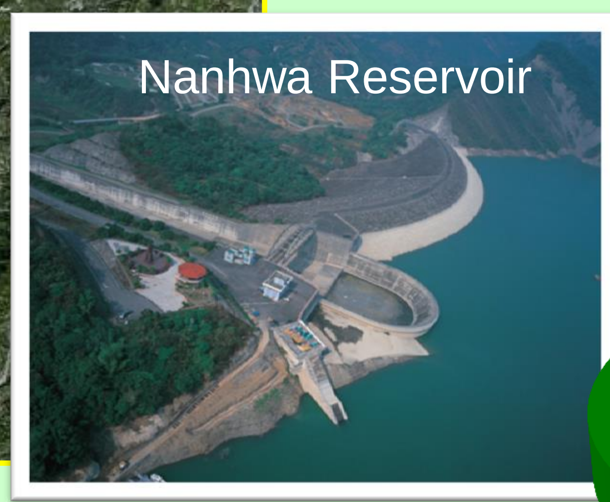
Change of reservoir storage



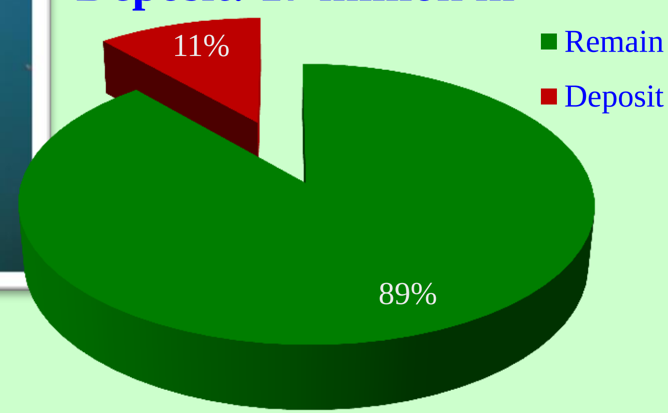


Capacity: 570 million m^3
Deposit: 90 million m^3

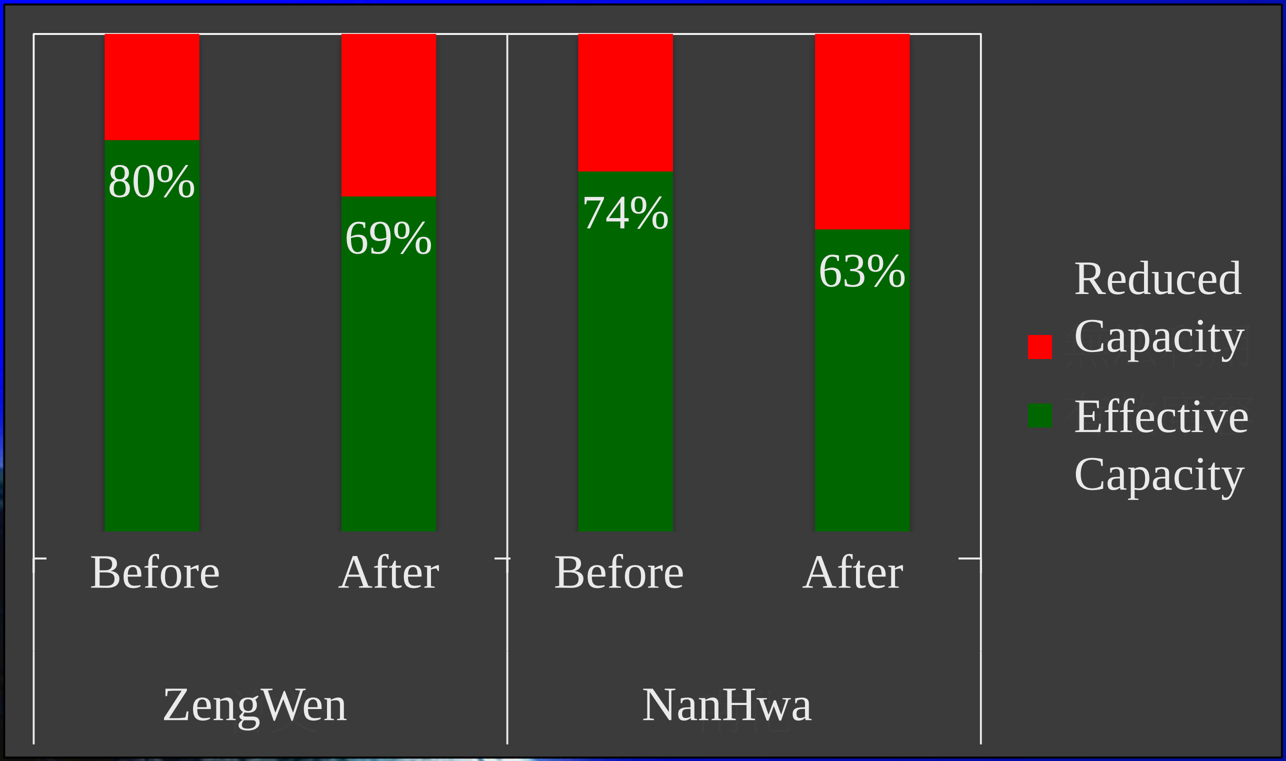




Capacity: 150 million m^3
Deposit: 17 million m^3



Typhoon Morakot Significantly Reduce Reservoir Effective Capacity

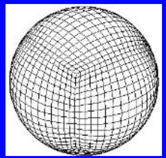


Learn From Typhoon Morakot

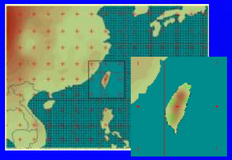
- Water shortage may not only be caused by insufficient streamflows, but also be induced by flood which results in high turbidity flows and facility malfunction.
- Extreme events may come frequently. Extreme flood follows serious drought, and then possible have another serious drought threat.
- Reservoir may be seriously reduced his capacity by a single event. A water supply system will become more and more vulnerable, if extreme events keep hitting the system before it can recover.
- Decreasing vulnerability and increasing resilience of a water supply system is urgent.

Future Possible Climate Change Impacts

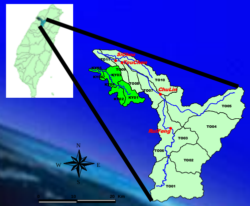
Impact Assessment



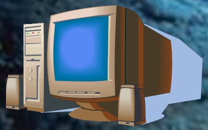
GCM Projections



Downscaling

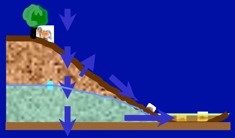


Future
Climate Scenarios

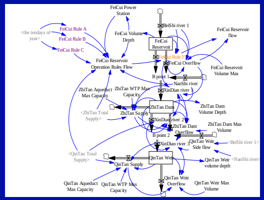


Weather Generation

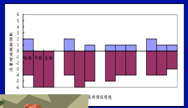
Hydrological Model

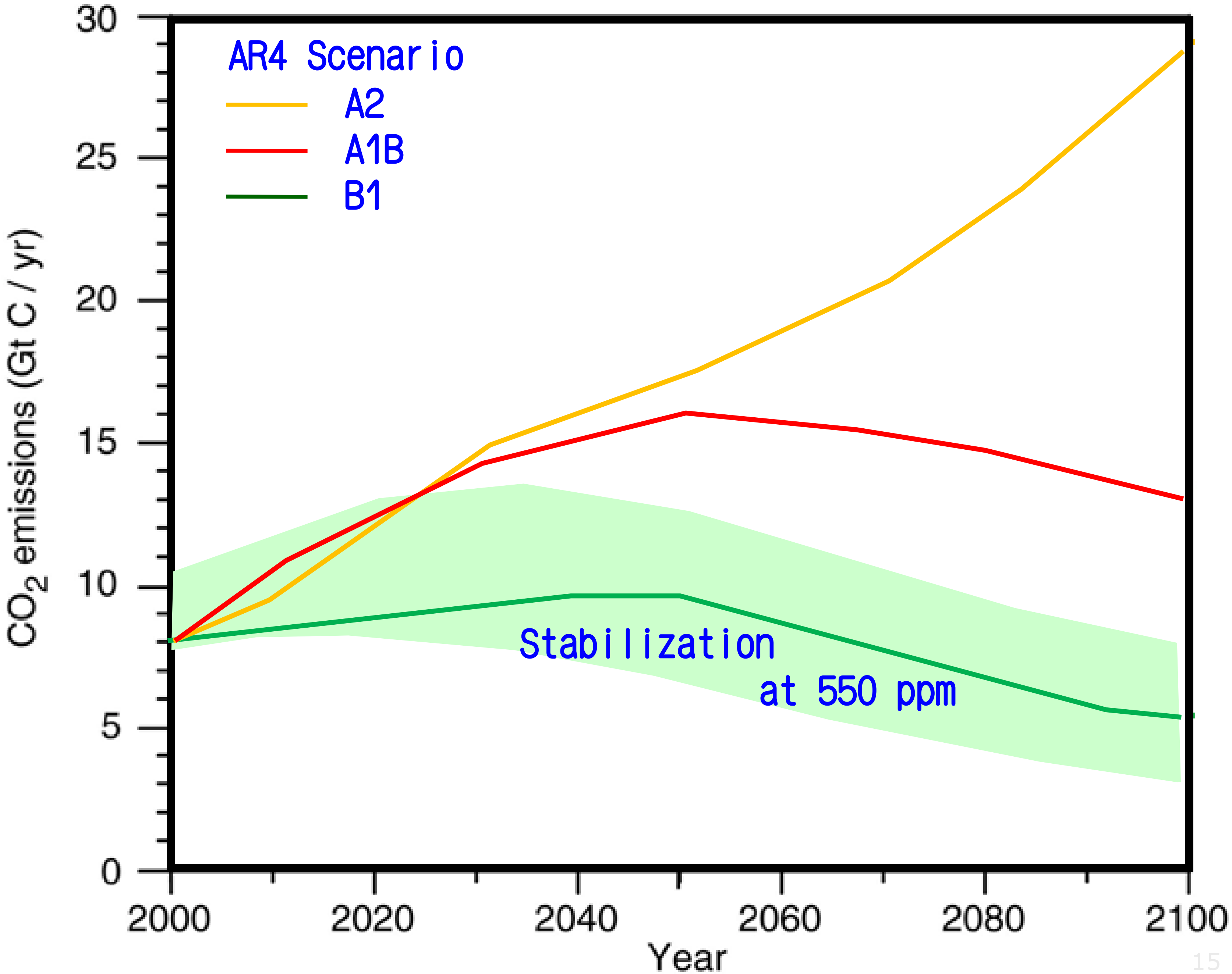


Water Supply System
Dynamics Model



Impact Inoformation for Decision Making





AR4 Scenario
A2
A1B
B1
Stabilization
at 550 ppm
CO_2 emissions (Gt C / yr)
Year
0
5
10
15
20
25
30
2000
2020
2040
2060
2080
2100

Correlation between Observation and GCMs' Baseline

Monthly Mean Temperature

	CSMK3	GFDL2.0	GFDL2.1	HadCM3	INM	IPCM4	MIMR	ECHAM5	CGCM2.3.2	NCAR
台南	0.99	0.99	0.99	0.98	1.00	0.99	1.00	0.98	0.97	1.00
阿里山	0.99	1.00	0.99	0.98	1.00	0.98	0.99	0.98	0.97	1.00
高雄	0.99	0.99	0.99	0.98	1.00	0.99	0.99	0.98	0.97	1.00

Monthly Mean Rainfall

	CSMK3	GFDL2.0	GFDL2.1	HadCM3	INM	IPCM4	MIMR	ECHAM5	CGCM2.3.2	NCAR
曾文新村	0.59	0.92	0.92	0.53	0.96	0.45	-0.13	0.97	0.82	0.93
西阿里關	0.58	0.93	0.91	0.54	0.97	0.44	-0.12	0.97	0.82	0.92
旗山(4)	0.58	0.93	0.91	0.53	0.97	0.45	-0.11	0.97	0.81	0.91
甲仙(2)	0.58	0.94	0.91	0.55	0.97	0.43	-0.11	0.97	0.81	0.91
美濃(2)	0.58	0.94	0.91	0.56	0.96	0.42	-0.10	0.97	0.82	0.92
三地門	0.59	0.95	0.92	0.61	0.95	0.40	-0.07	0.98	0.79	0.91
六龜(4)	0.56	0.94	0.91	0.55	0.97	0.45	-0.11	0.98	0.82	0.91
梅山(2)	0.44	0.93	0.83	0.54	0.94	0.34	-0.18	0.93	0.86	0.91

Downscaling Method

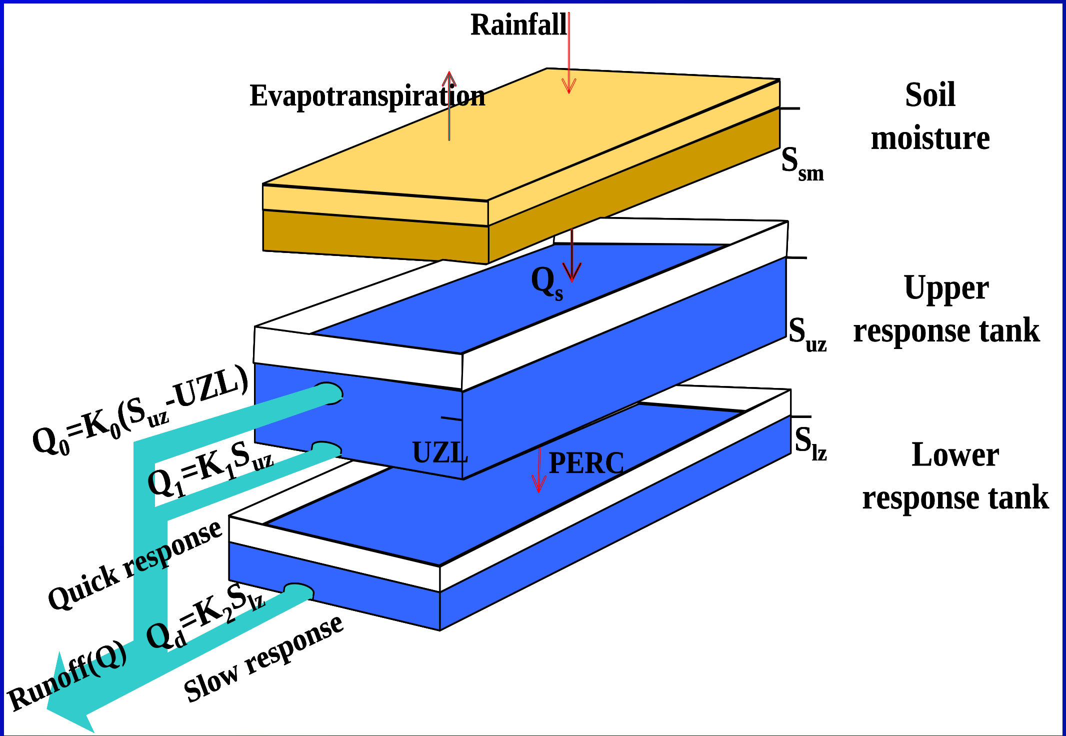
- Simple Downscaling
  - Delta Method
  - Bias Correlation

Simulation Models

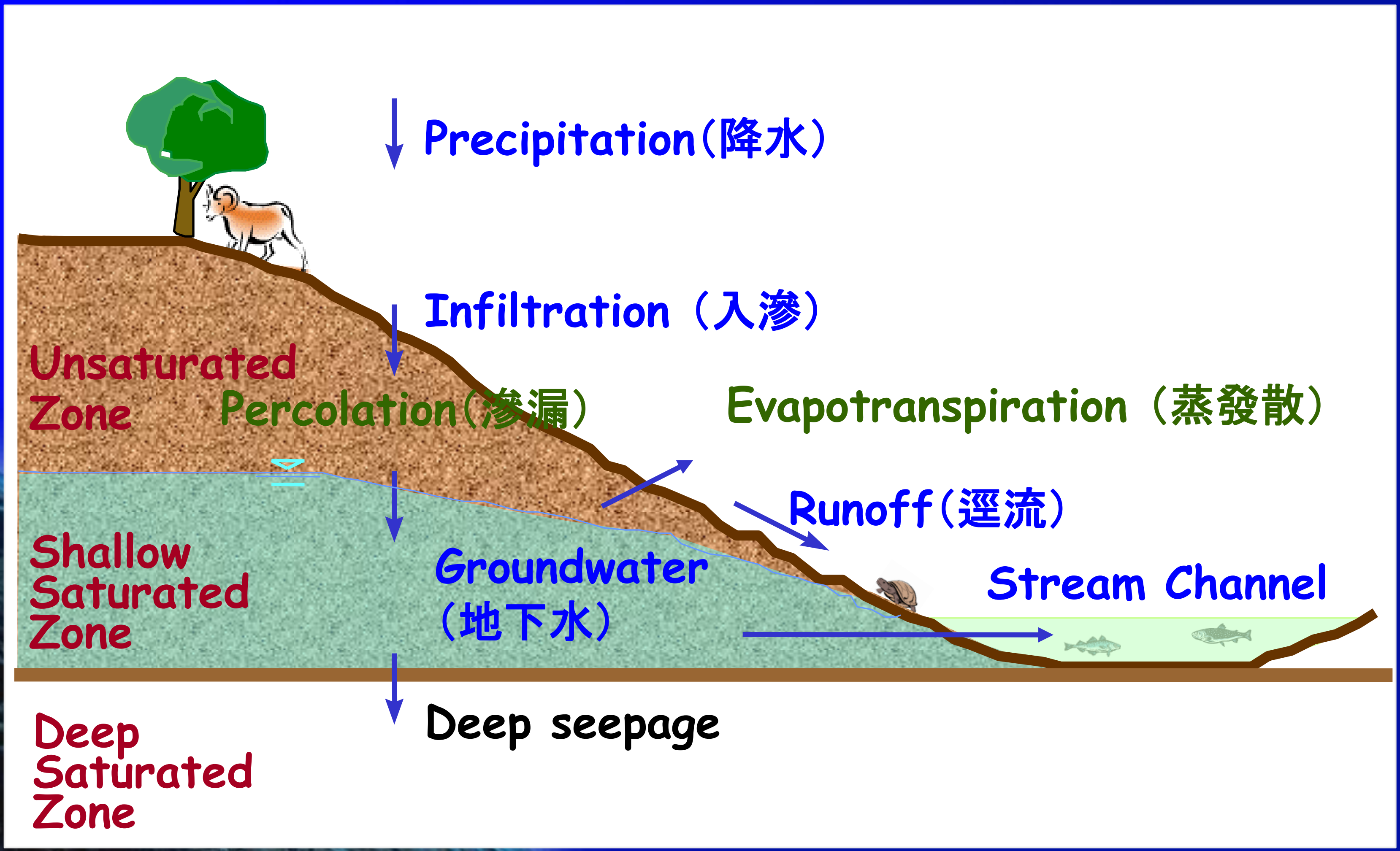
- Weather Generation Model produce daily weather data based on different climate scenarios.
- Hydrological Models – HBV and GWLF simulate current and future streamflows.
- Water Supply System Dynamics Model – It is developed by Vensim System Dynamics Modelling tool.

HBV Model

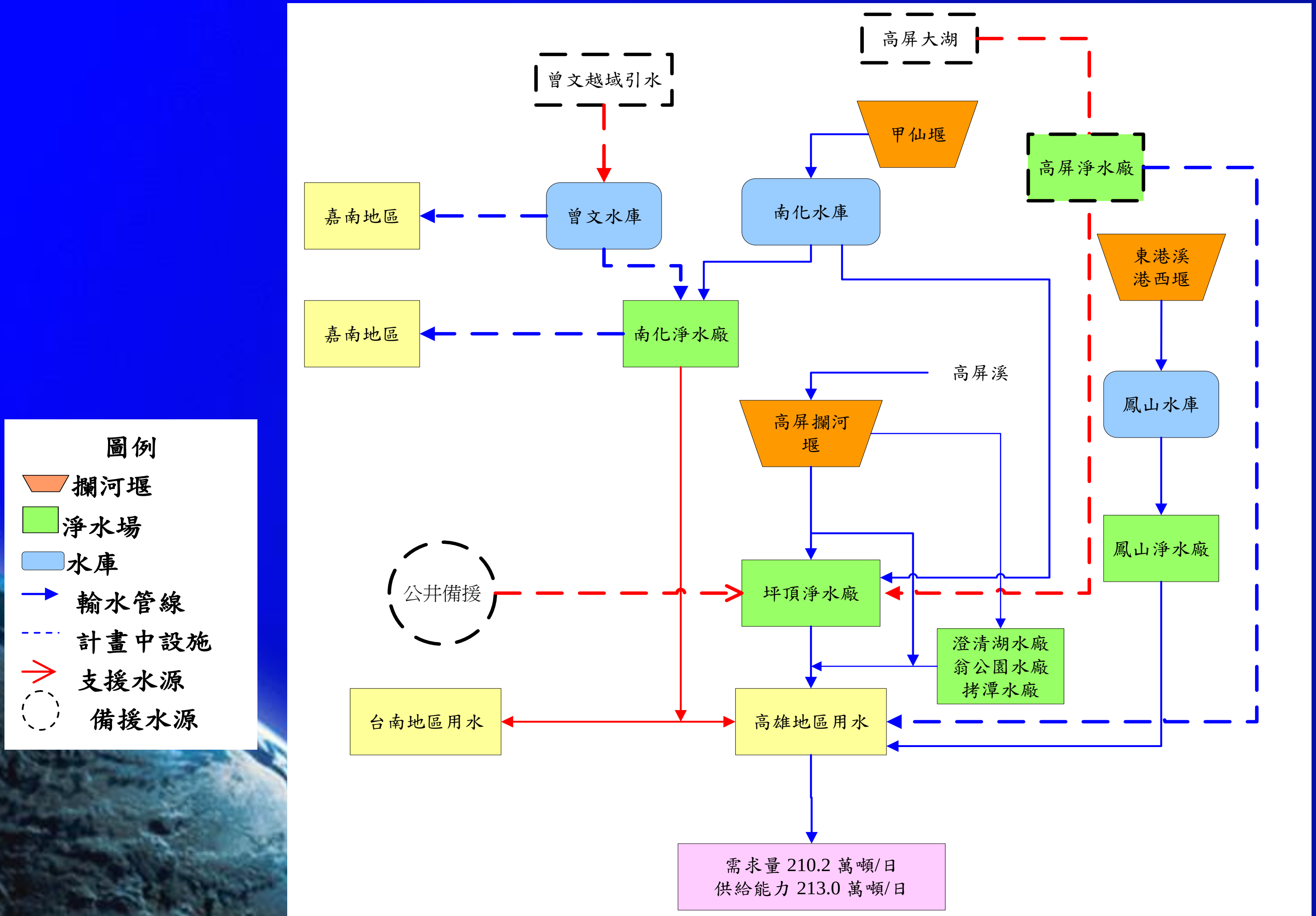
- Parameters
  - *FC*(Field Capacity)
  - *β*、*LP* (Parameter)
  - *UZL*(Outflow height)
  - *Recession Coefficient*
    - K_0 (UZL)
    - K_1 (upper tank)
    - K_2 (lower tank)
  - *Ce* (coefficient of ET)
  - *PERC* (Percolation)



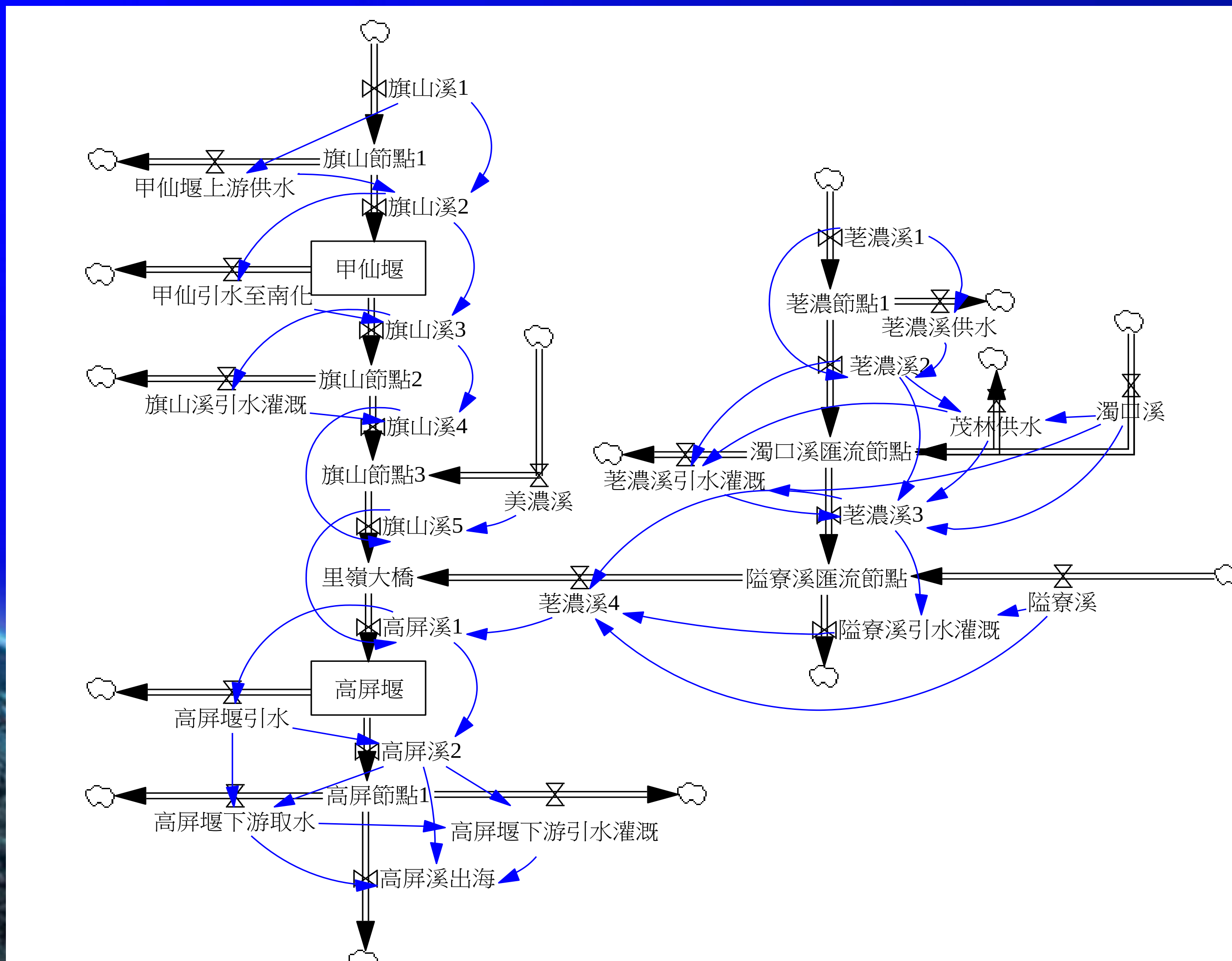
Streamflow component of the GWLF model



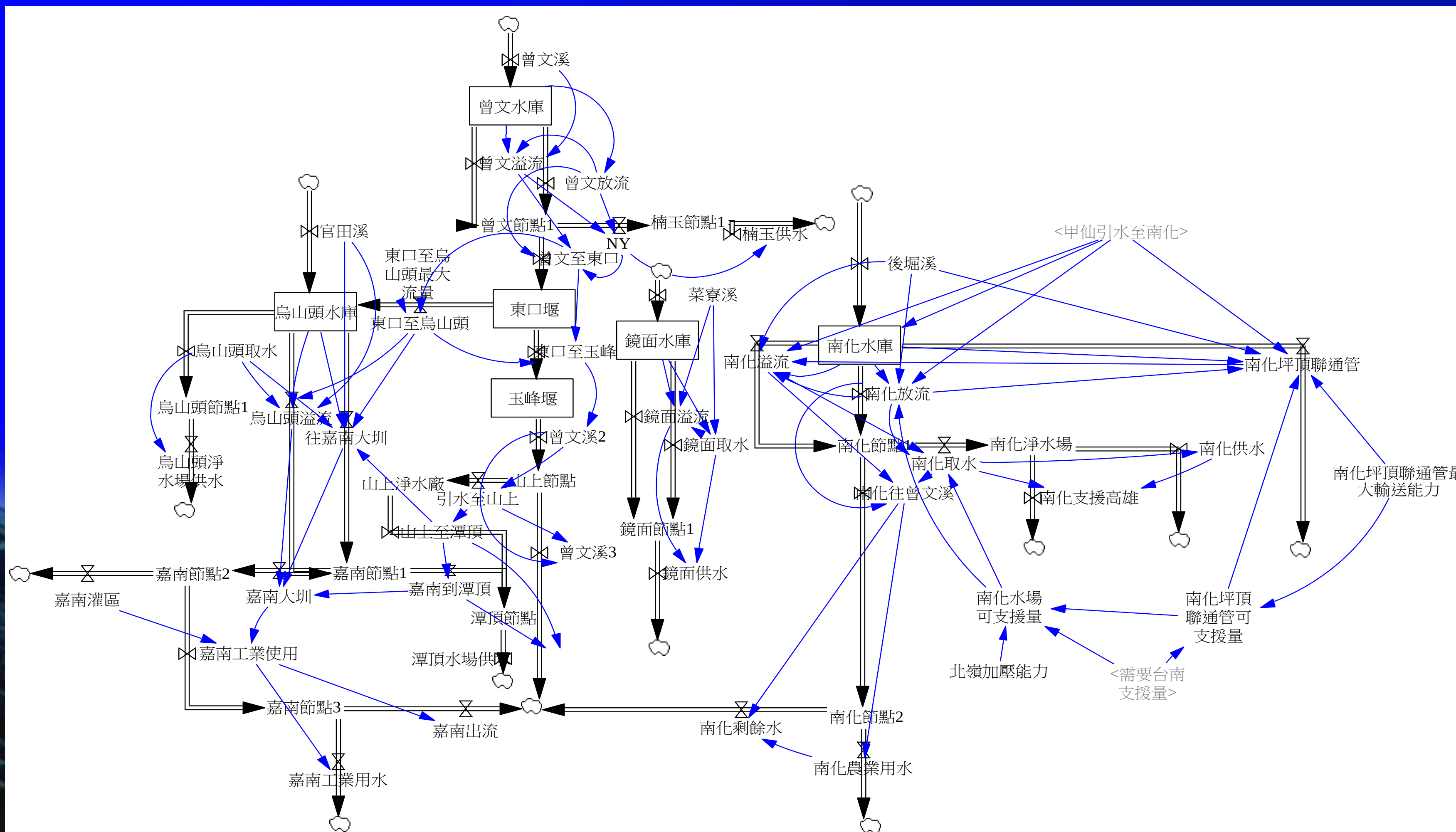
Water Supply System - Gaoping Area



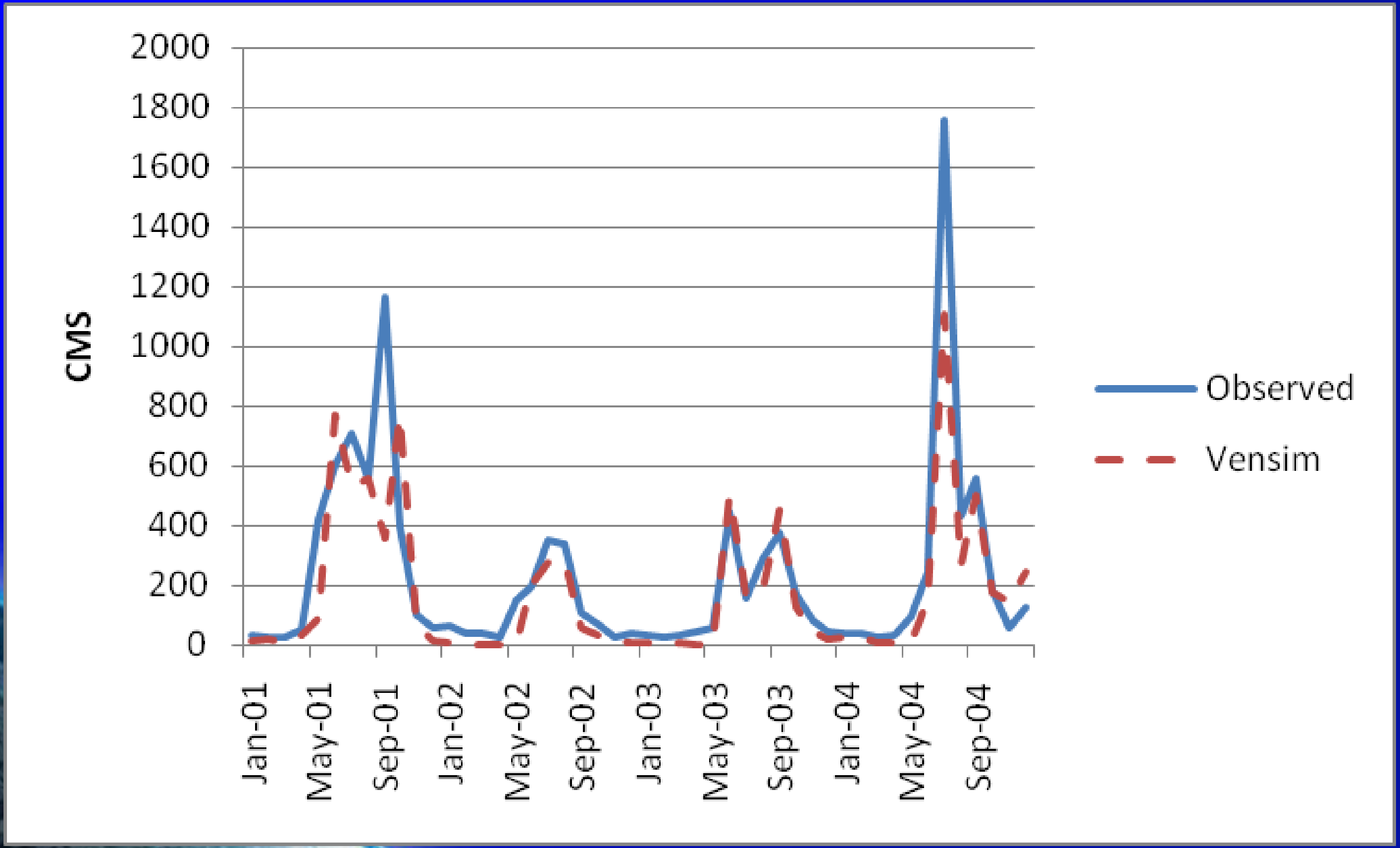
Water Supply System Dynamics Model - the Gaoping System



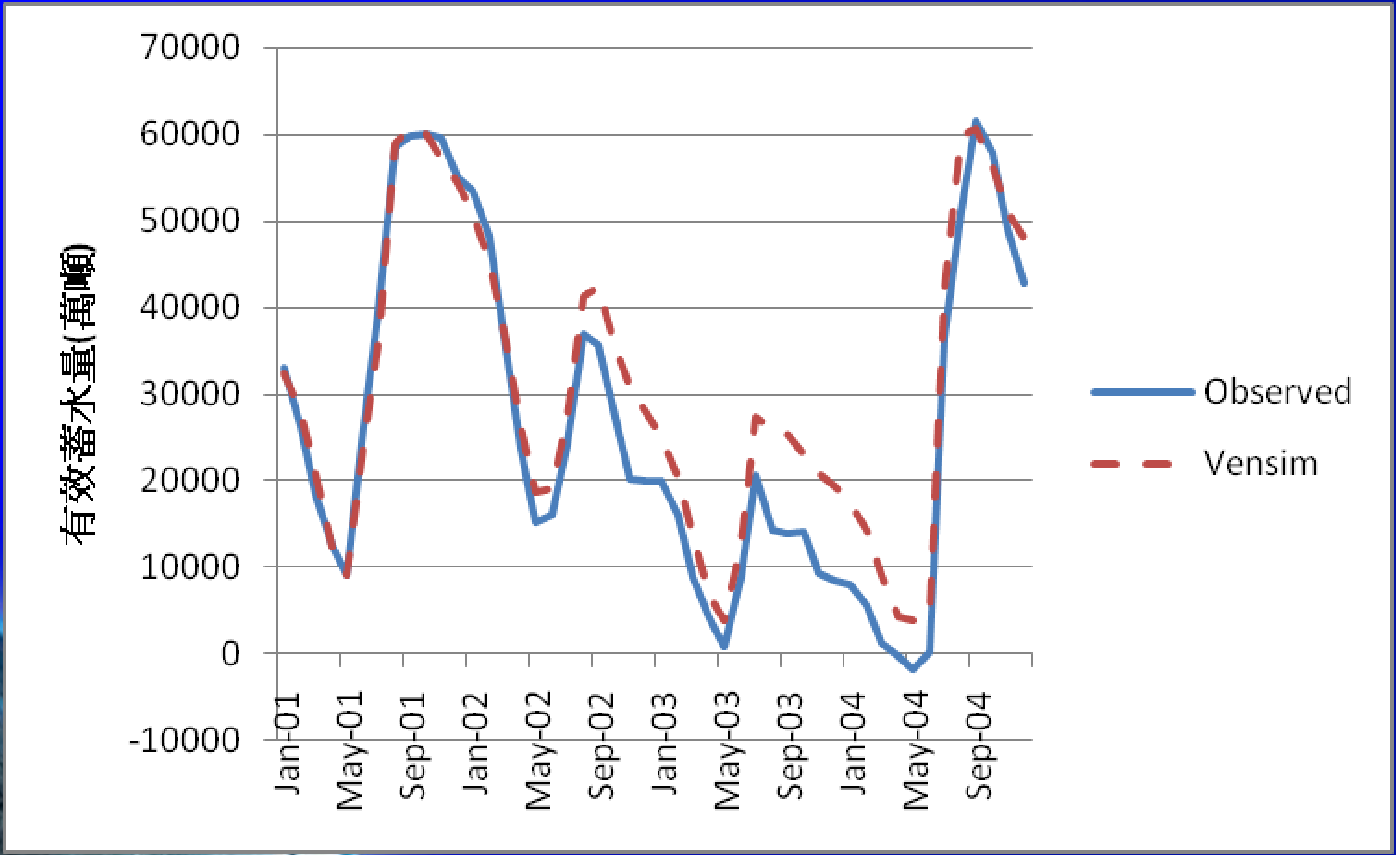
Water Supply System Dynamics Model - the Zengwen Creek system



Verification of System Dynamics Models - Flows @ Liling Bridge Gage Station



Verification of System Dynamics Models - Storage @ Zengwen Reservoir



Index to evaluate the risk of water deficit

- Shortage Index

$$SI = \frac{100}{N} \sum_{i=1}^{N} \left(\frac{D_i}{S_i}\right)^2$$

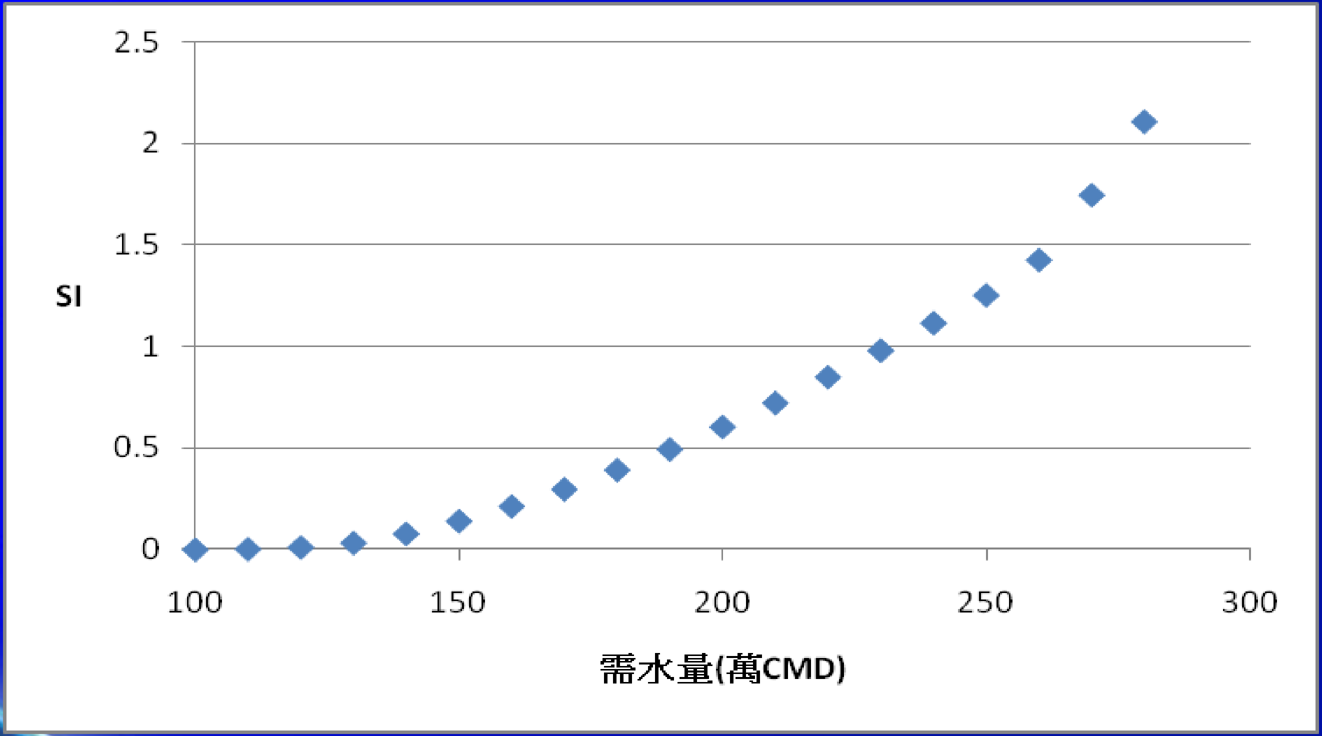
- Deficit Percent Day Index, DPD Index

$$DPD = \sum_{d=1}^{N_d} D\%$$

The Criteria of Water Deficit

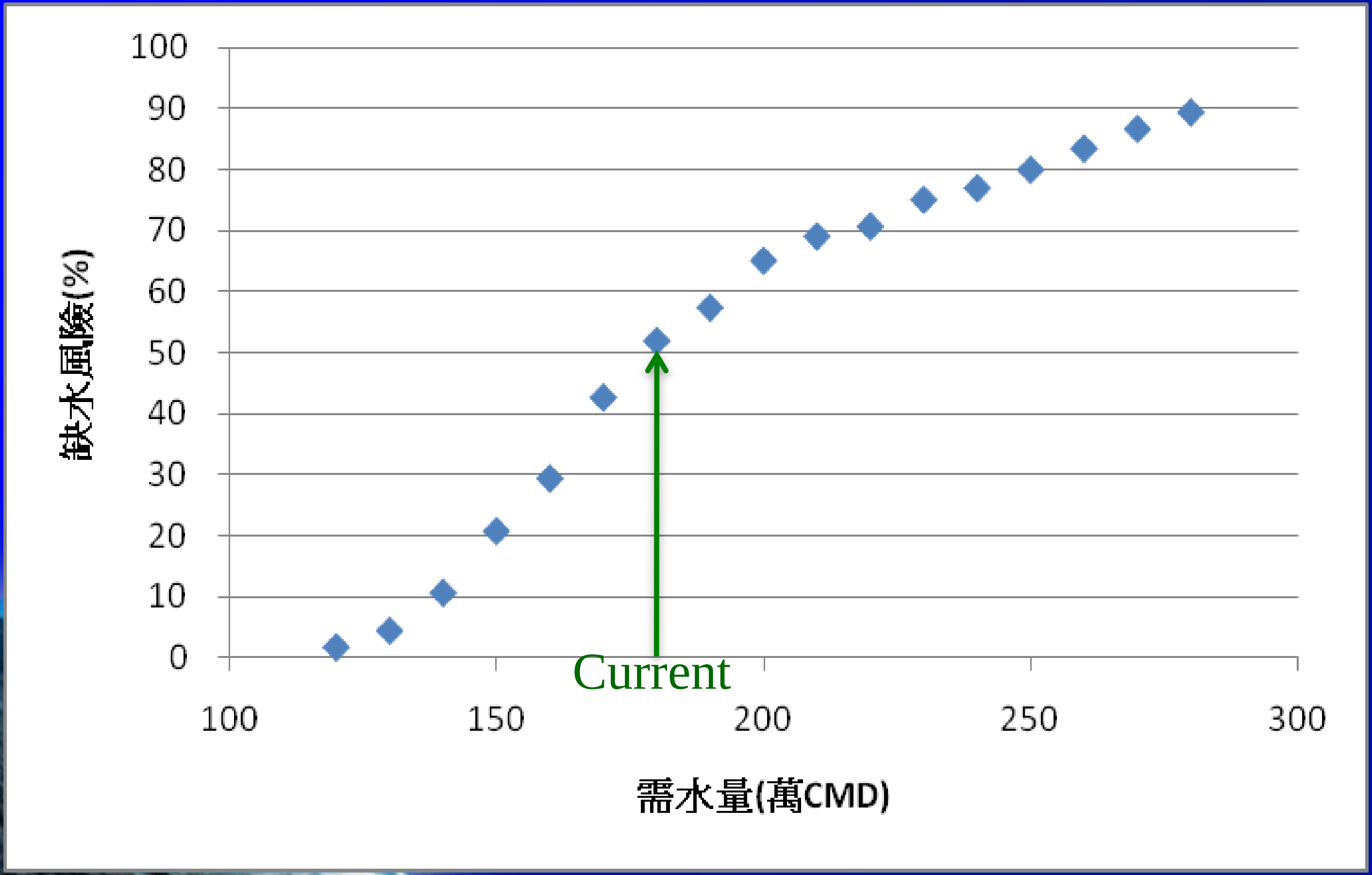
- Current shortage index (SI) is about 0.39 which is used as a reference.
- This study uses the threshold of DPD=1500 %-day to evaluate the water supply ability.

Current Water Supply Carrying Capacity

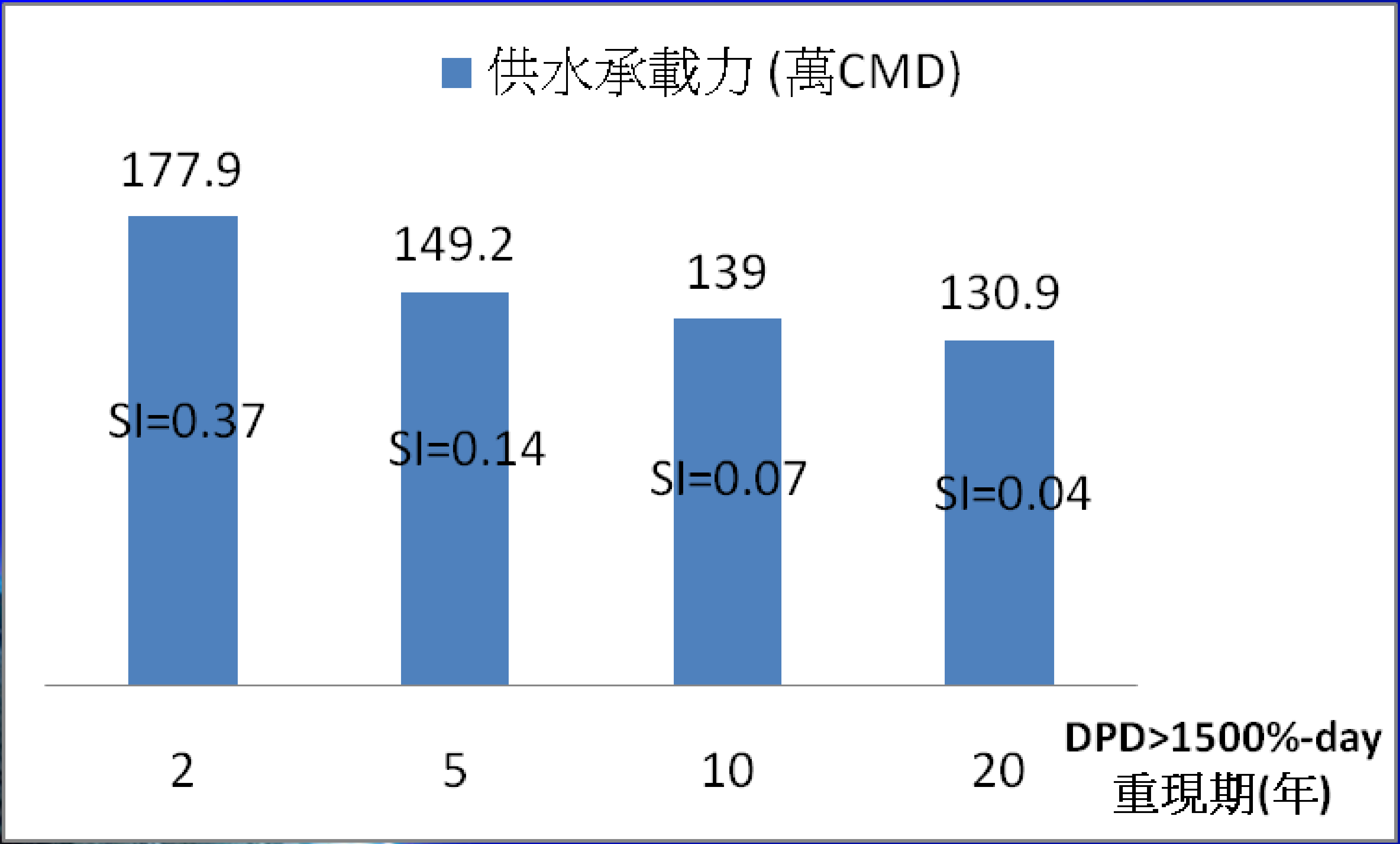


SI	0.1	0.5	1	Current 0.39
Water Supply (10^4CMD)	143.5	190.6	231.5	180

Risk of Water Deficit with the criterion of DPD>1500%-day



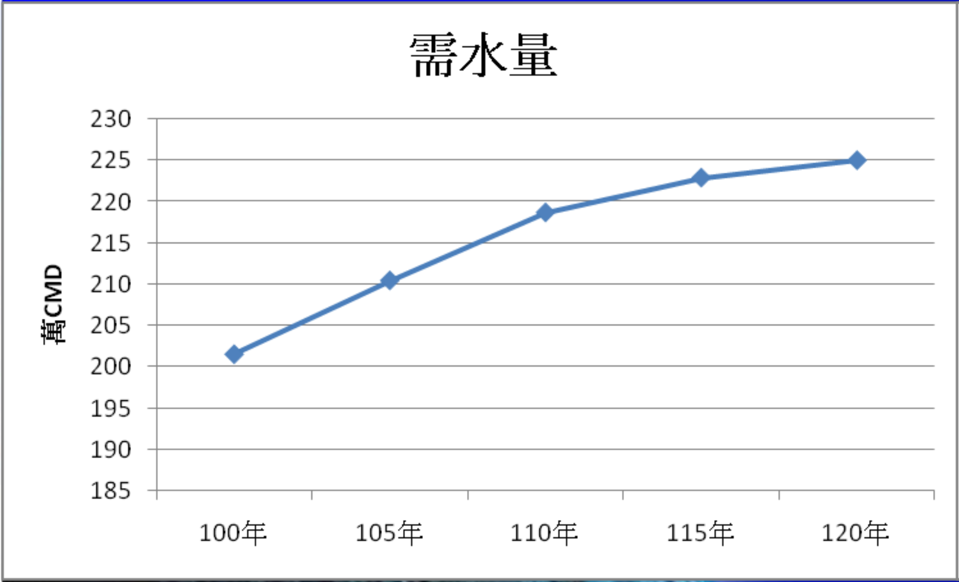
Current Carrying Capacity of Water Supply System

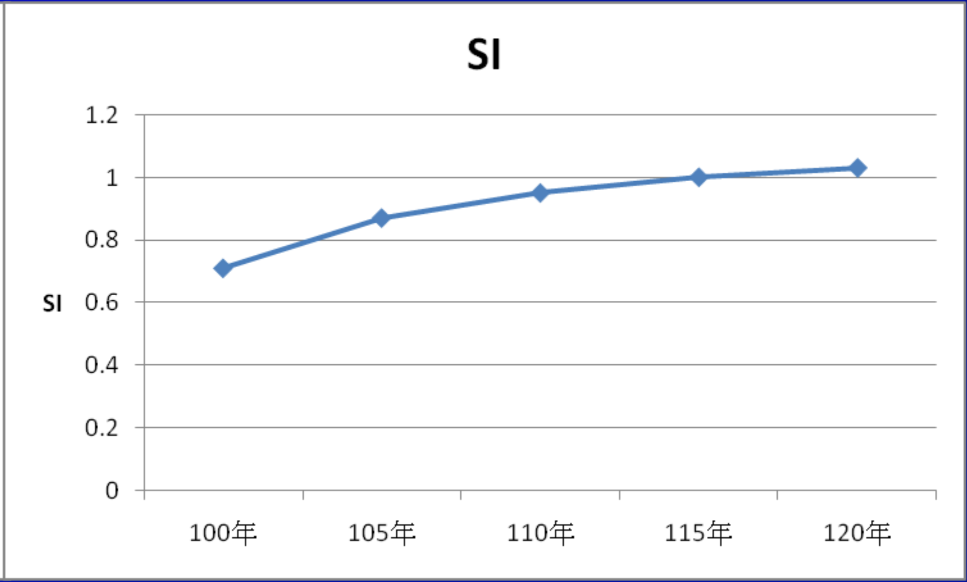


Project Future Water Demand due to growth of Industry and Population

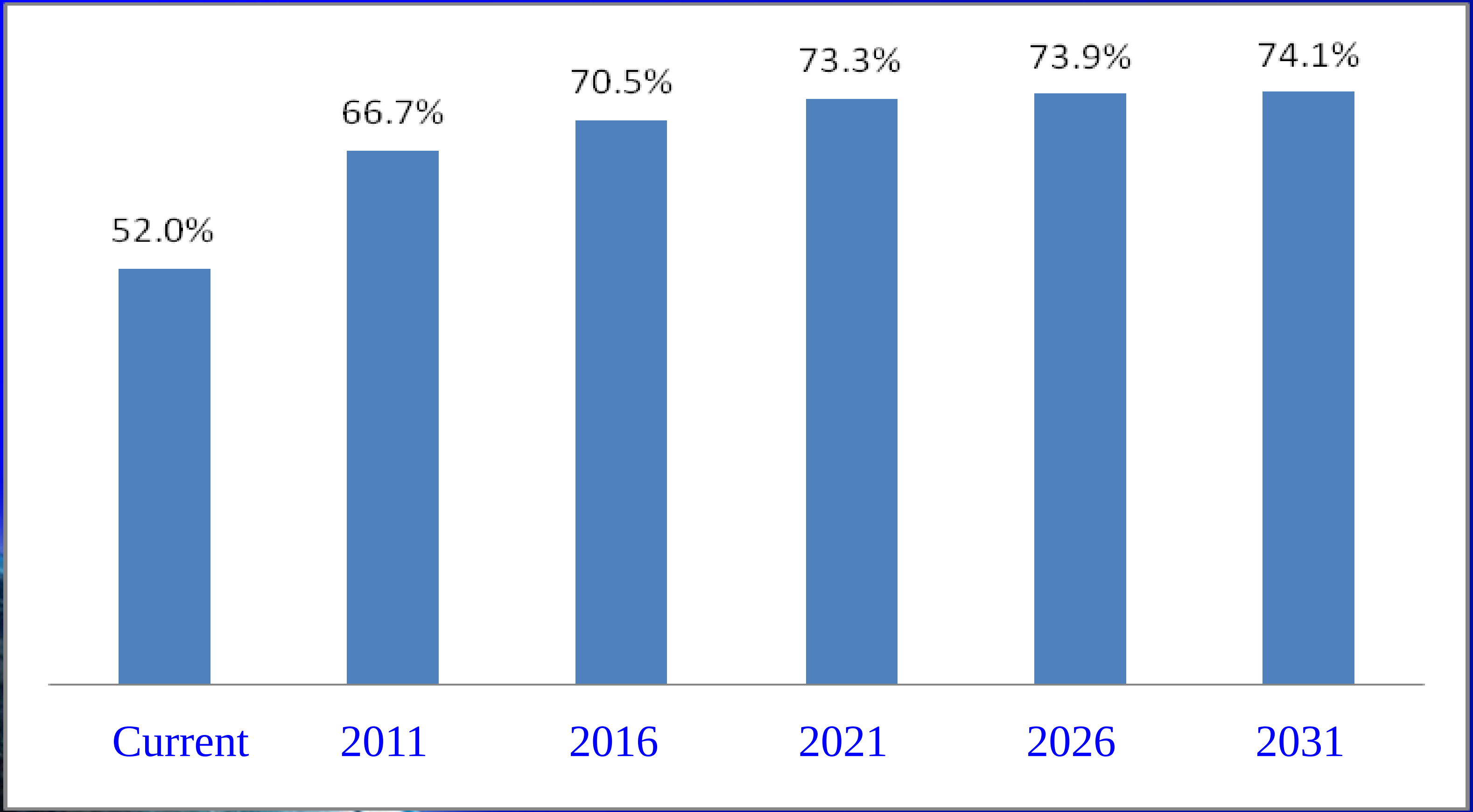
	2011	2016	2021	2026	2031
Demand	201.6	210.5	218.7	222.9	225
SI	0.71	0.87	0.95	1.00	1.03

Unit : 10^4CMD





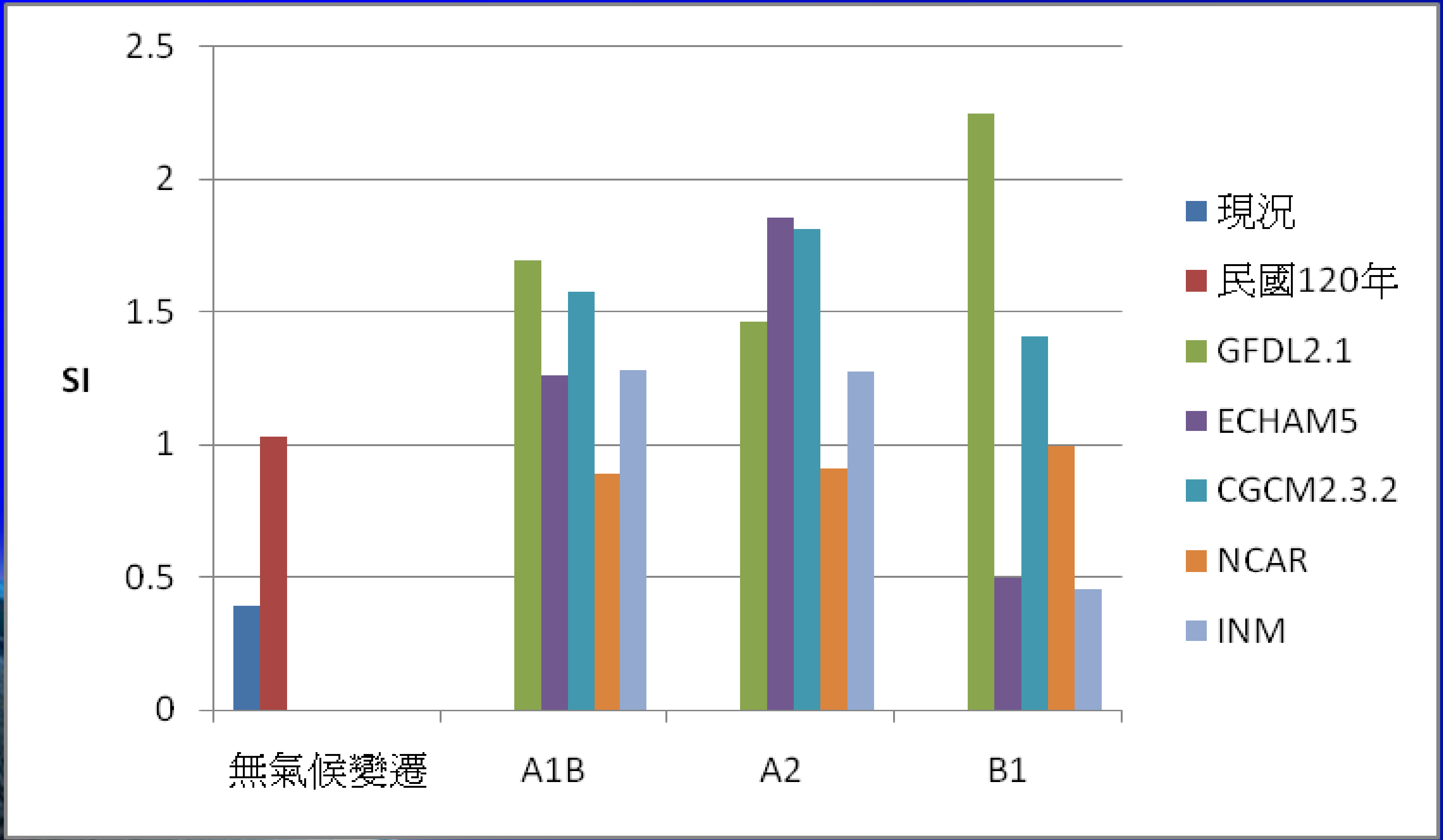
Risk of Water Deficit (DPD>1500%-day)



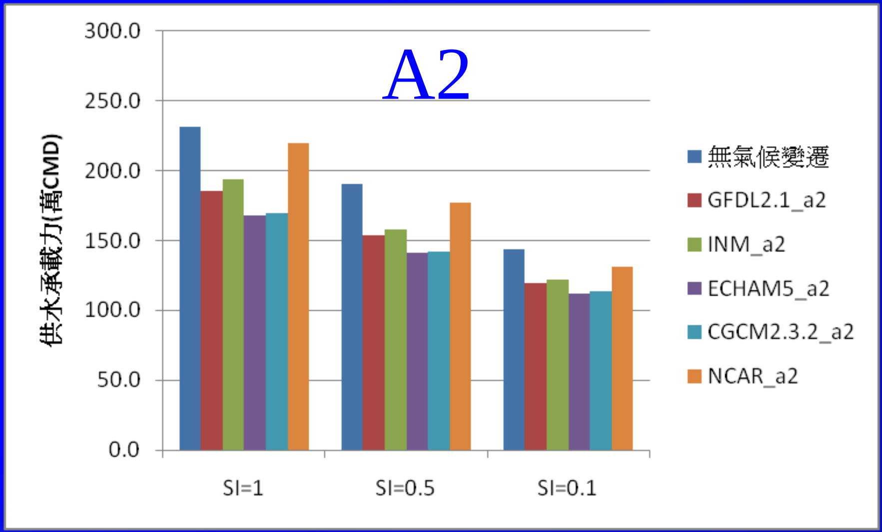
Climate Change Impacts on Gaopin Water Supply Carrying Capacity@2031

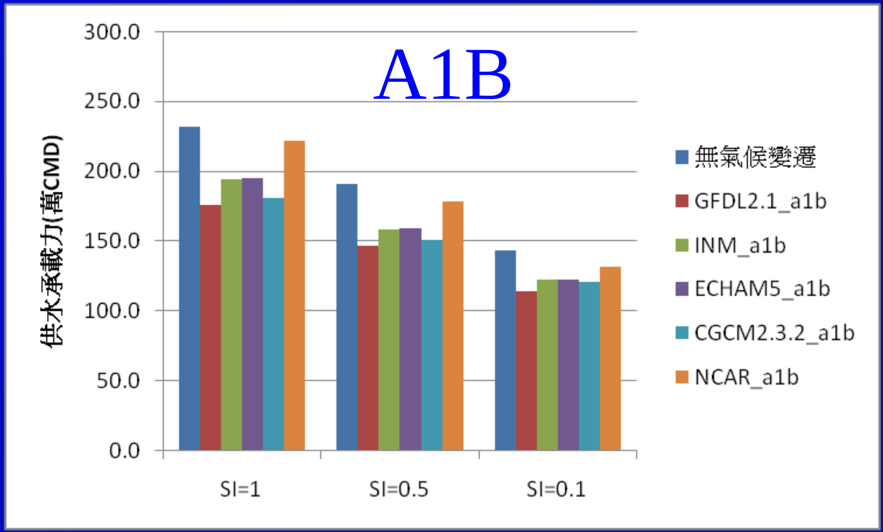
	SI=1	SI=0.5	SI=0.1
W/O Climate Change	231.5	190.6	143.5
GFDL2.1_a1b	175.9	146.7	114.5
INM_a1b	193.9	158.2	122.7
ECHAM5_a1b	195.3	159.3	122.4
CGCM2.3.2_a1b	180.5	150.9	121.2
NCAR_a1b	221.5	177.9	131.5
GFDL2.1_a2	185.5	153.9	119.9
INM_a2	193.6	157.6	122.3
ECHAM5_a2	168.4	140.8	112.2
CGCM2.3.2_a2	169.5	142.0	113.8
NCAR_a2	219.9	177.3	131.5
GFDL2.1_b1	157.3	132.9	103.7
INM_b1	268.8	218.4	149.1
ECHAM5_b1	264.1	213.0	149.6
CGCM2.3.2_b1	187.0	153.8	121.9
NCAR_b1	213.0	171.5	129.6

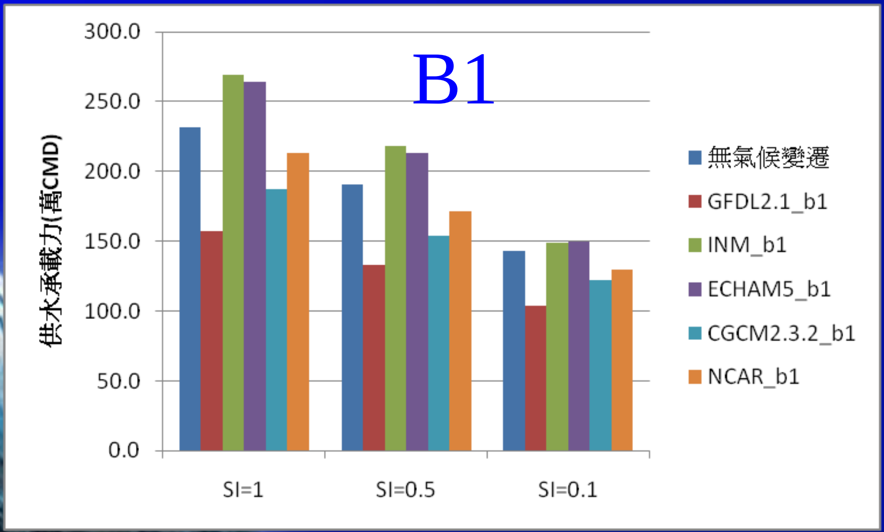
Climate Change Impacts on Gaoping Water Supply Carrying Capacity



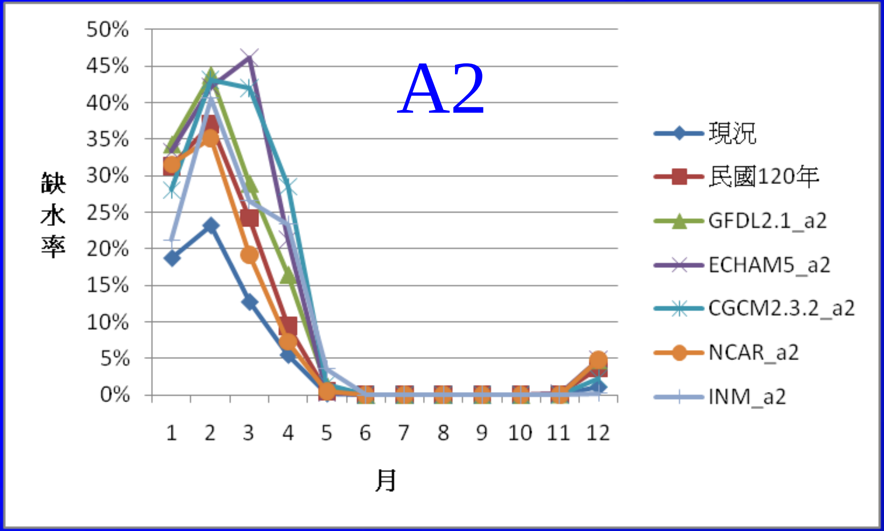
Climate Change Impacts on Gaopin Water Supply Carrying Capacity@2031

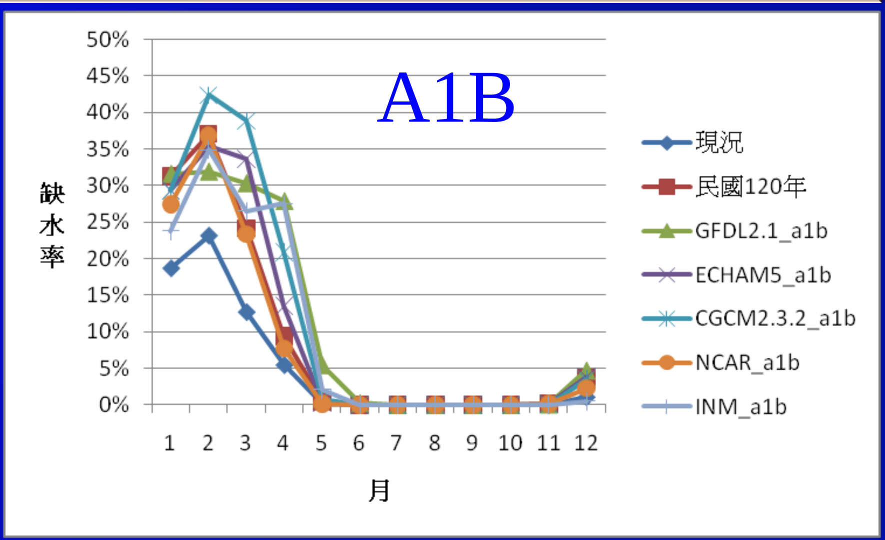


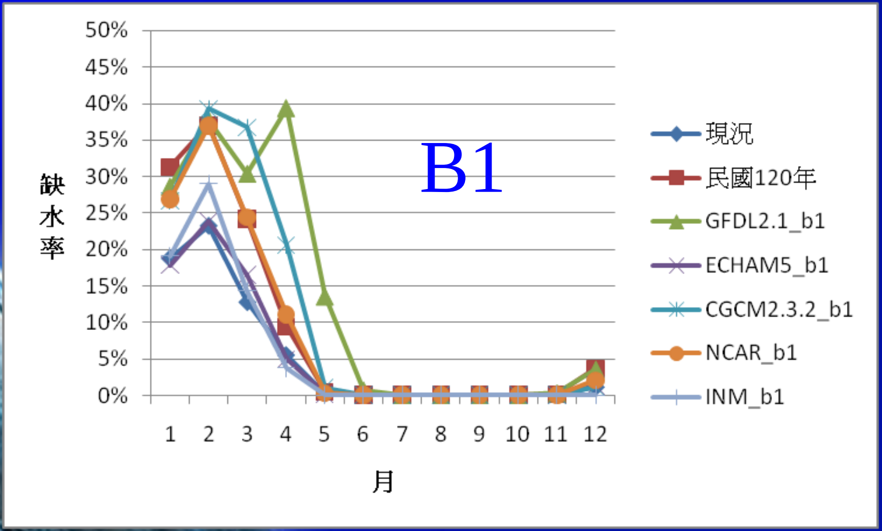




Climate Change Impacts on Gaopin Water Supply Carrying Capacity@2031







Strengthening the Adaptive Capacity of Water Supply Systems

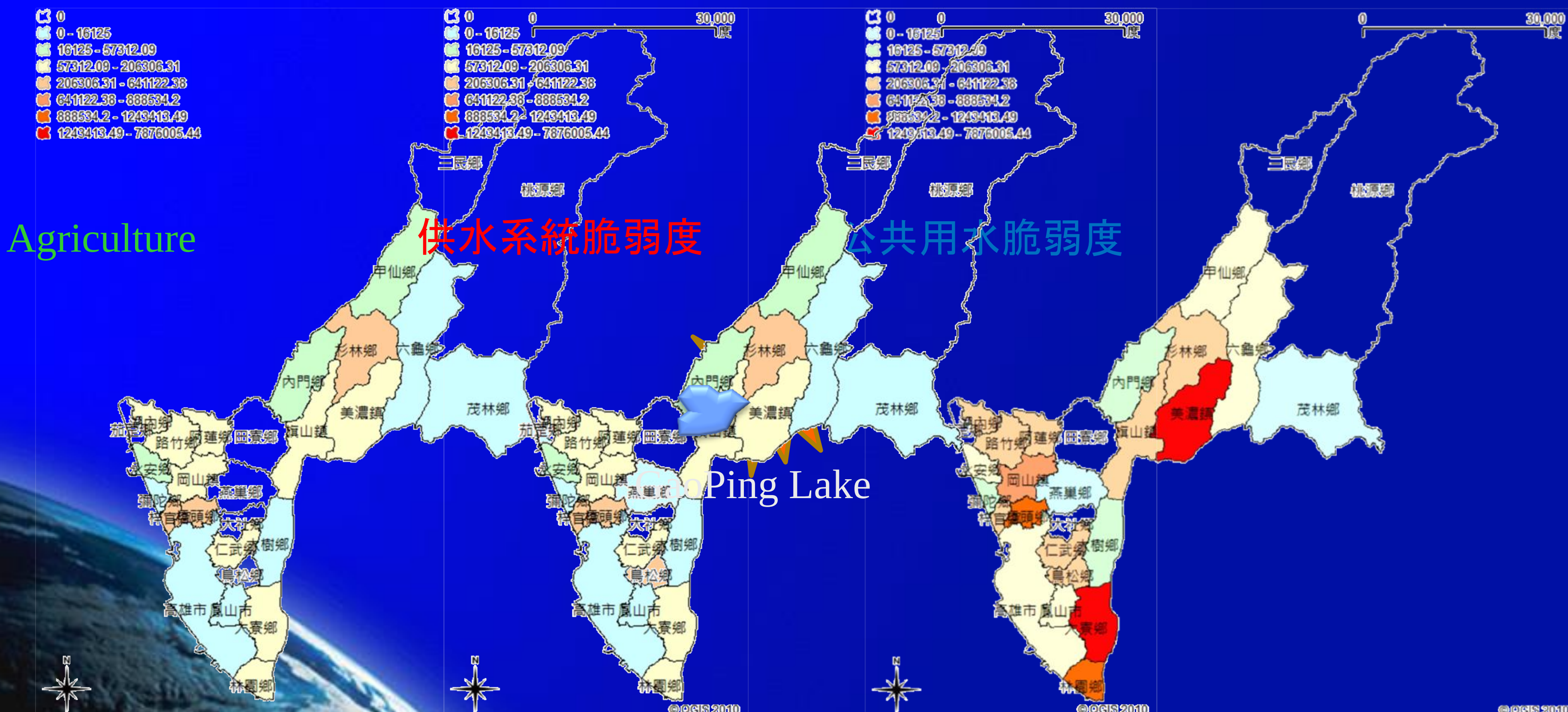
Which spot is vulnerable?

Climate Proofing System

Goals

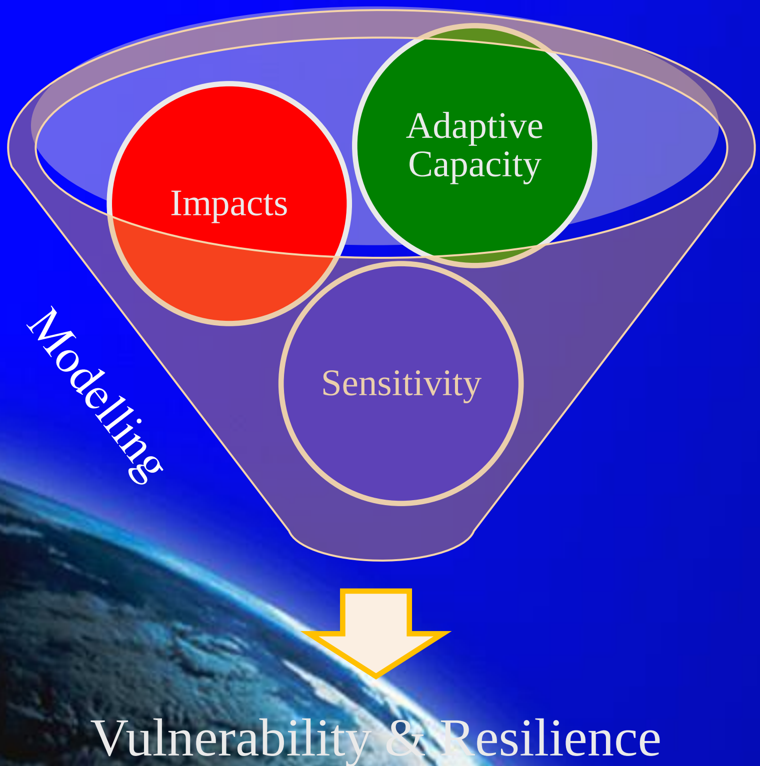
- Identifying hotspot (the most vulnerable areas)
- Developing distributed response systems

Establishing Vulnerable Maps



Vulnerability Assessment

V= F (Impact, Adaptive Capacity, Sensitivity)



- Impacts
  - Changing Climate
- Adaptive capacity
  - Facilities
  - Governance & Management
- Sensitivity (Exposure)
  - Population
  - Agricultural and Industrial Productions

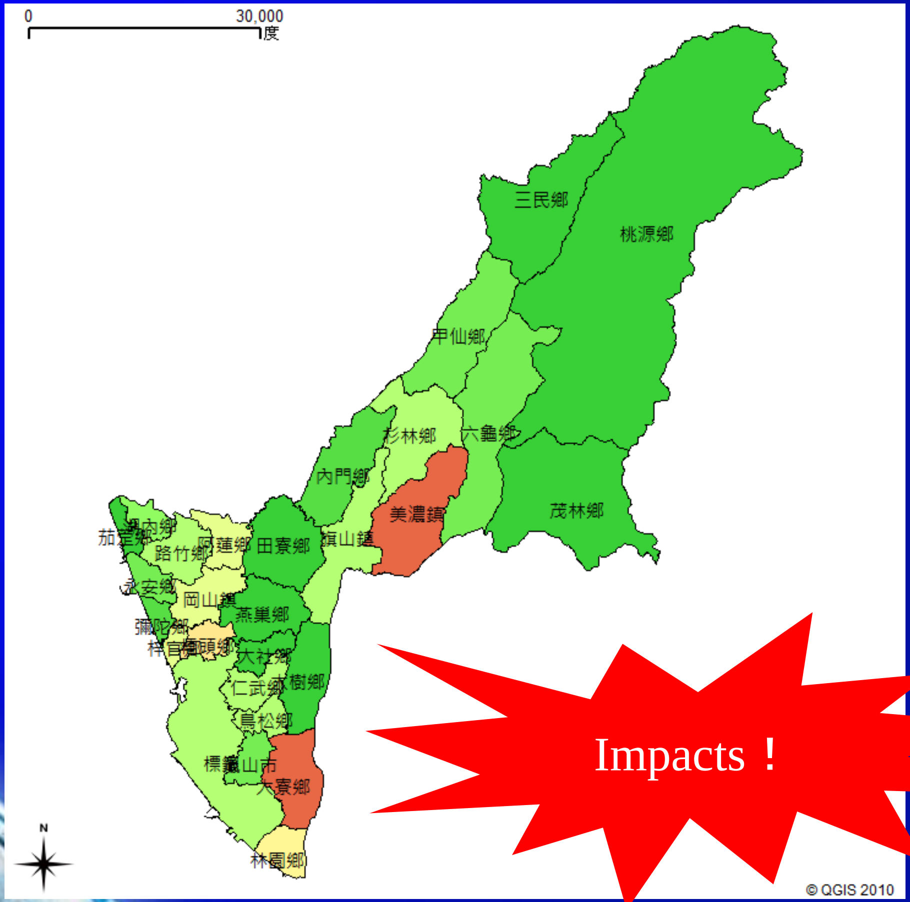
Vulnerability Map

Climate Scenarios

A1B

A2

B1



Impacts！

Adaptation Strategies

Strategy 1

Strategy 2

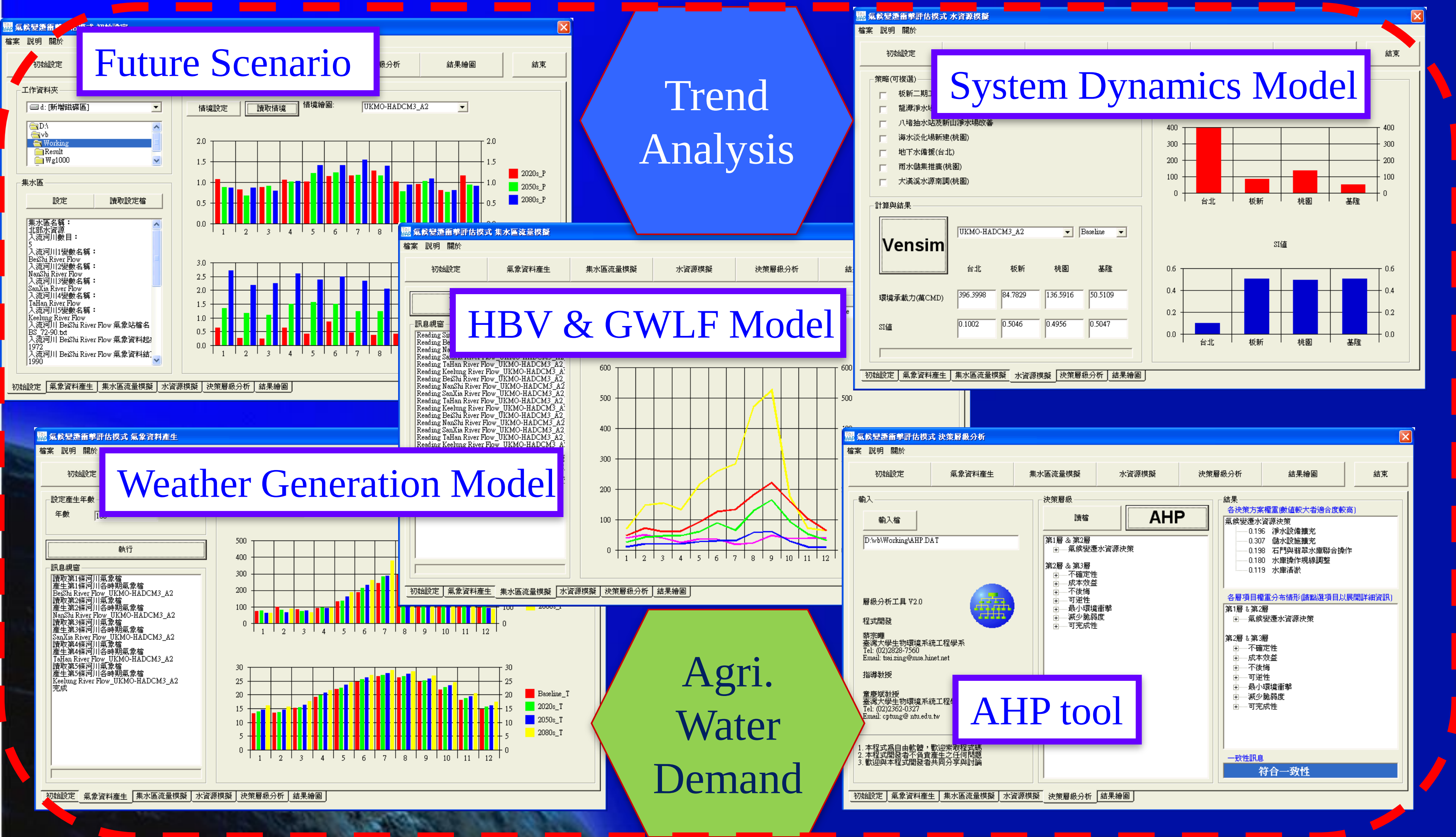
Strategy 3

Back

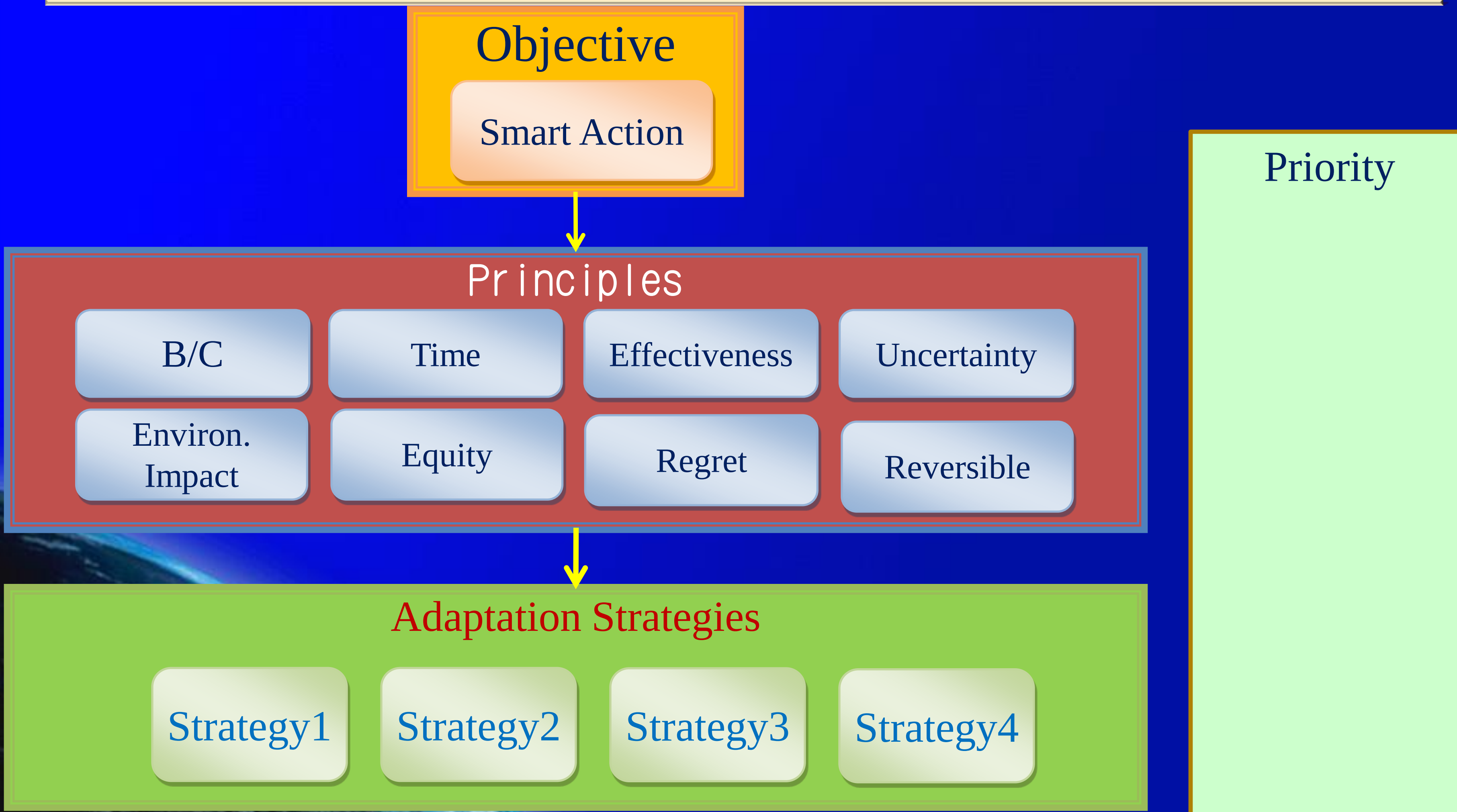
Taiwan Water Resources Assessment Program to Climate Change (TaiWAP)

http://groups.google.com.tw/group/taiwap2

Components in TaiWAP



AHP Tool



Objective
Smart Action
Principles
B/C
Time
Effectiveness
Uncertainty
Environ. Impact
Equity
Regret
Reversible
Adaptation Strategies
Strategy1
Strategy2
Strategy3
Strategy4
Priority

Final Remarks

- Sustainable development is our goal. The abilities to evaluate climate change impacts and identify measures to strengthen adaptive capacity are very important to reach the goal.
- Engineer always designs their systems based on past statistics and assumes they are stationary. However, climate change makes different stories.
- How to reduce vulnerability and increase resilience for a system is very important.

Final Remarks

- How can we make wise decisions with uncertainty?Uncertainty is the major constraint on taking actions. Early warning and risk management systems are very important for adapting to future climate.
- Distributed response system may also be required to unload impacts. Possible measures for distributed response system may include rainwater harvesting, water recycling, groundwater, small lake, etc..

Thanks for Listening!
Any Question is Welcomed!

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