

# THE GROUNDWATER RESOURCES AND MANAGEMENT PRINCIPLES IN TAIWAN

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2021/10/15



# Outline

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- Groundwater reserves and resources in Taiwan
- Relation Framework of Groundwater Management
- Groundwater management practices in Taiwan
- Groundwater management strategies in Taiwan
  - Short-Term Strategies
  - Long-Term Strategies
- Management Principle beyond strategies

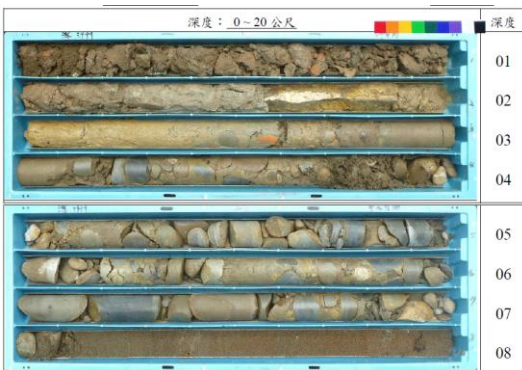
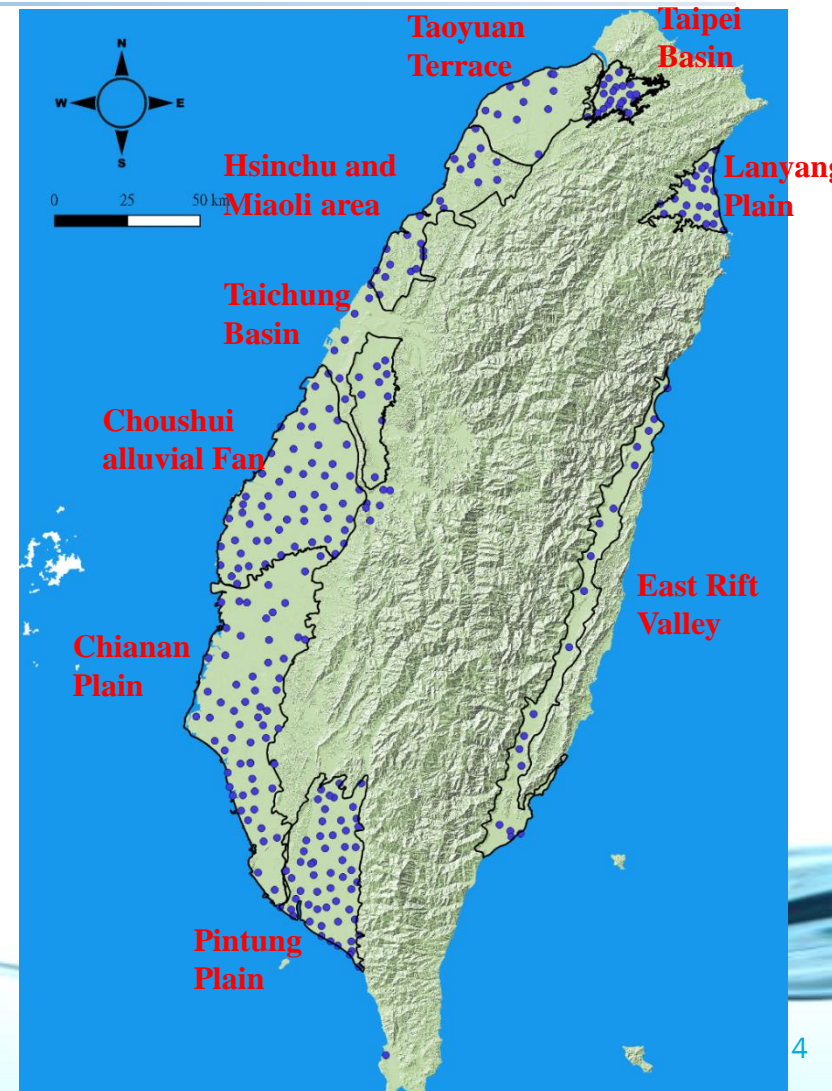
# **THE GROUNDWATER RESERVES AND RESOURCES IN TAIWAN**

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**(THE NATURE GROUNDWATER STATE IN TAIWAN)**

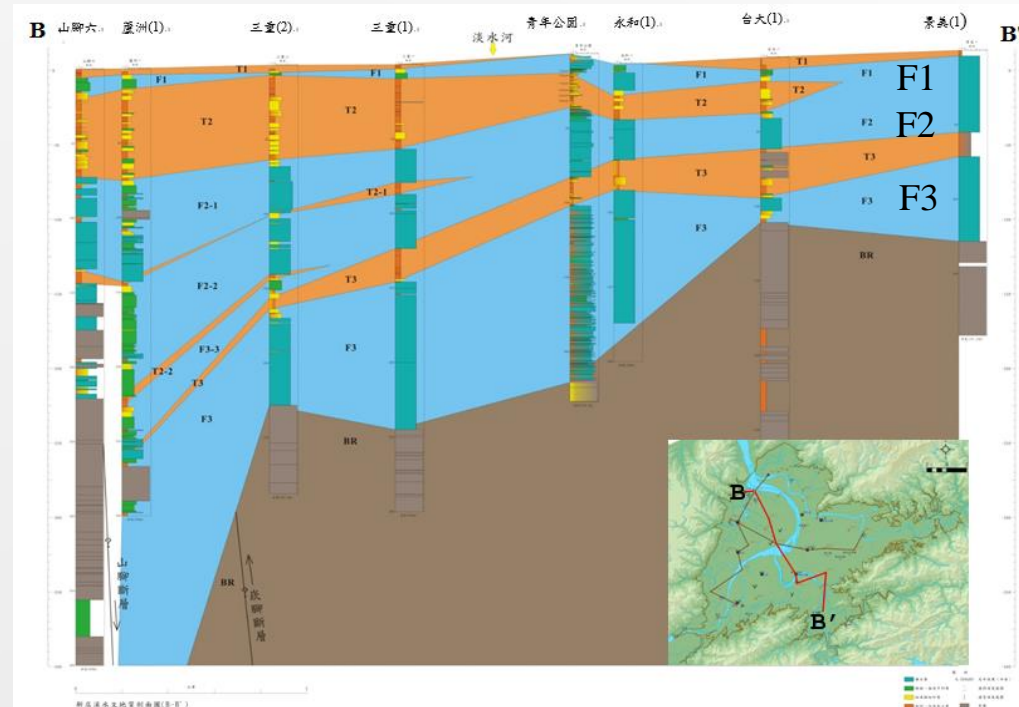
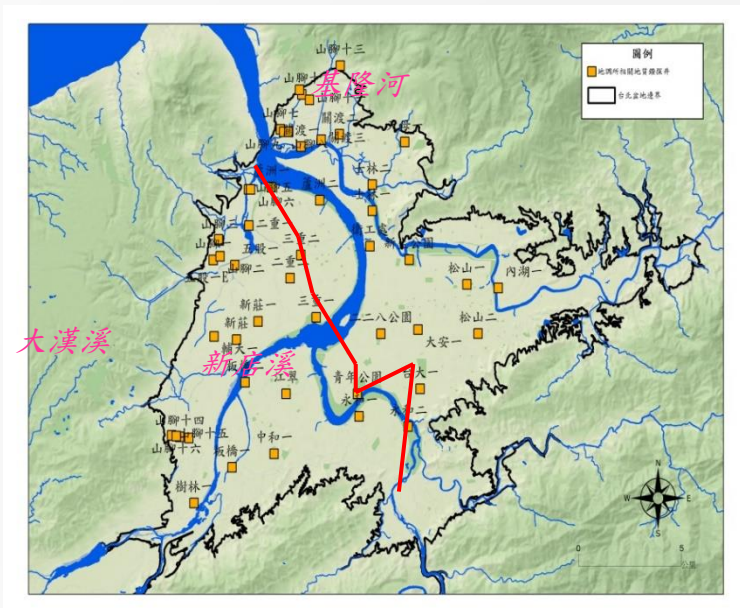
# Groundwater Monitoring Network in Taiwan

- There are seven groundwater basins in Taiwan main island.
- 825 monitoring wells were established in 17 years during 1993 to 2009.
- 332 geological drillings were conducted.
- The hydrological data collected during the network establishment and the groundwater level observed by the network are the basis for all the groundwater study.



# Geological Profile \_Taipei basin

- Within 60 meter depth, a thick and widely distributed clay-sand layer formed a **regional aquitad** in the Taipei basin.
- The main aquifer is a **confined aquifer** and has low surface recharge.
- Pumping can cause **significant groundwater drawdown** and induce land subsidence.

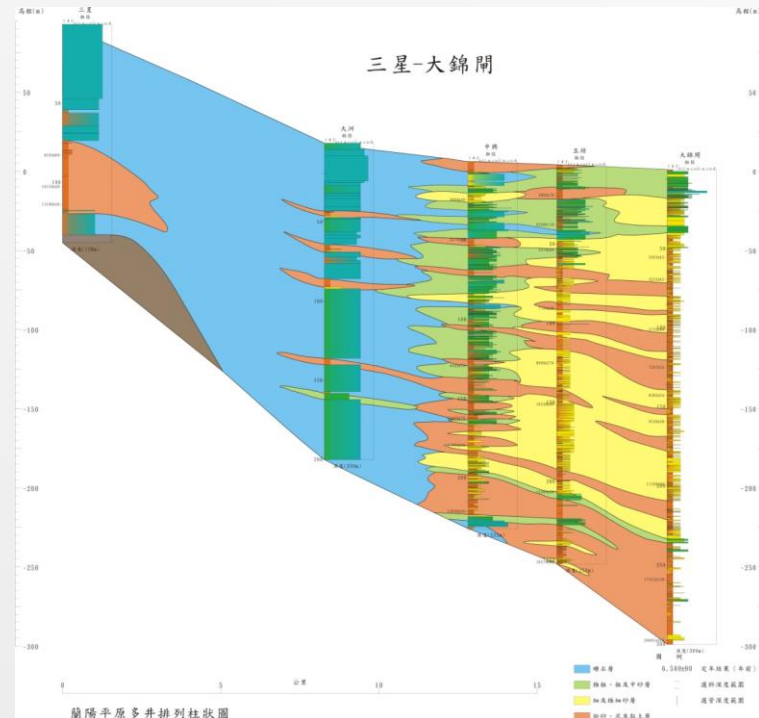


(Profile from Central Geological Survey)



# Geological Profile \_Lanyang Plain

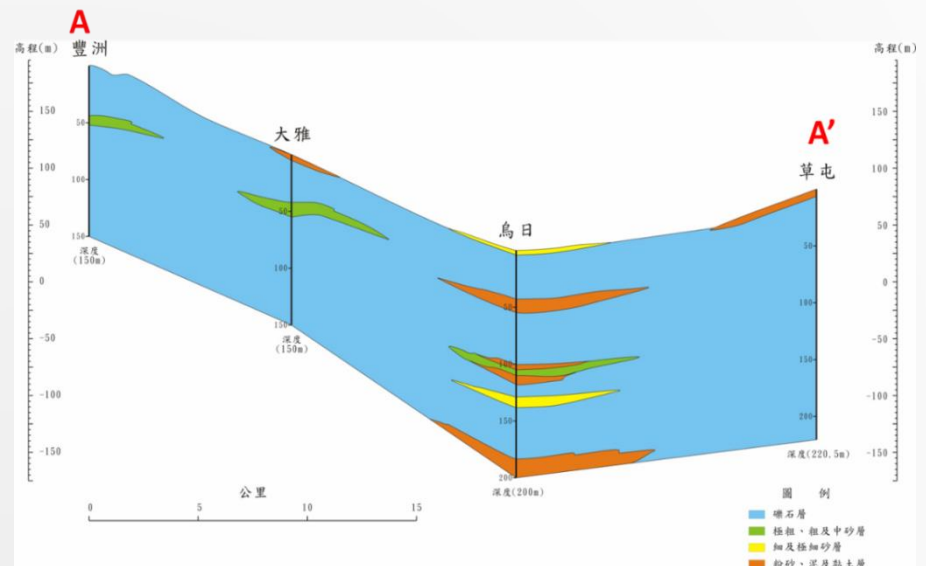
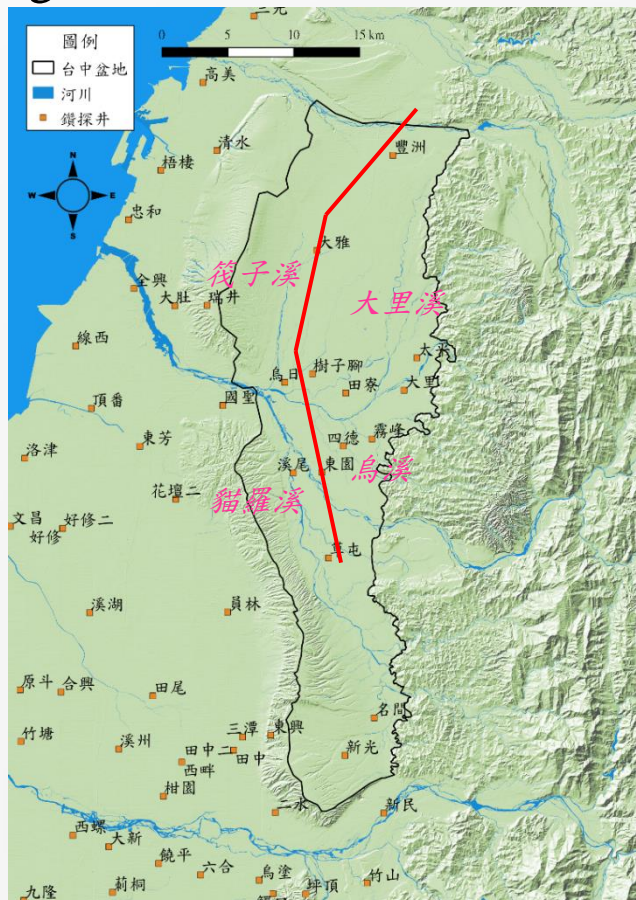
- A typical river delta. Upstream of the alluvial fan is a thick gravel deposition ( $> 200$  m) and is a rich aquifer.
- Middle to downstream of the fan has fine grain deposition
- The geological condition can sustain considerable groundwater drawdown without significant deformation



(Profile from Central Geological Survey)

# Geological Profile \_Taichung Basin

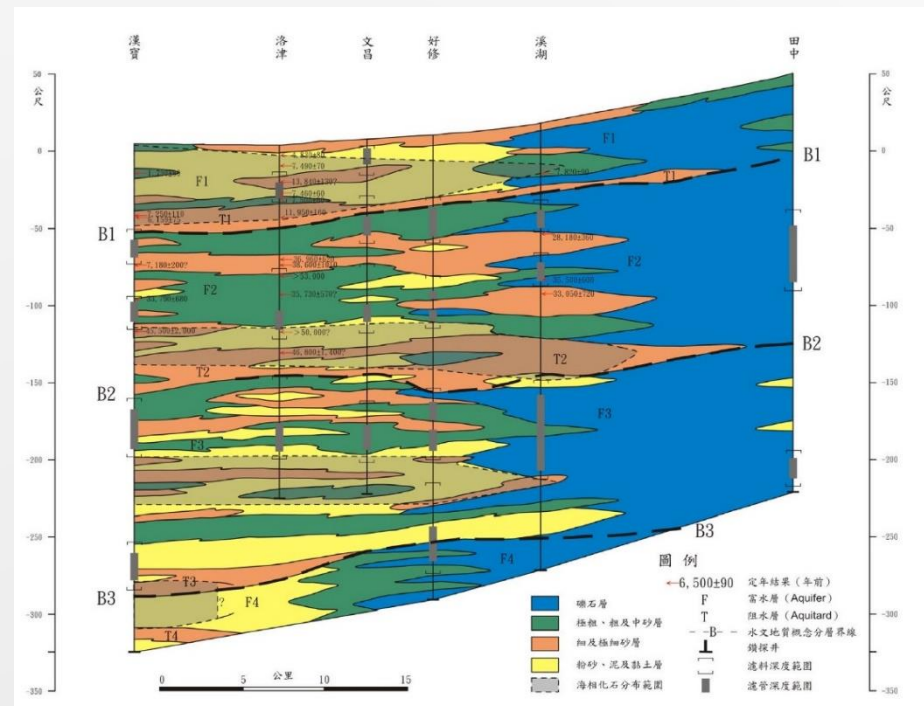
- Most area is gravel. Only a few clay layers exit in Wuri area. The basin has rich groundwater aquifers and can sustain considerable groundwater drawdown.



(Profile from Central Geological Survey)

# Geological Profile \_Zhuoshuixi Alluvial Fan

- Upstream alluvia fan consists of gravel with high hydraulic conductivity. Middle to downstream fan is a complicated layer system consists of clay, sand and gravel. The alluvia fan has rich groundwater aquifers in general.
- Downstream of the fan including coastal area consists considerable clay layers and should avoid groundwater pumping.

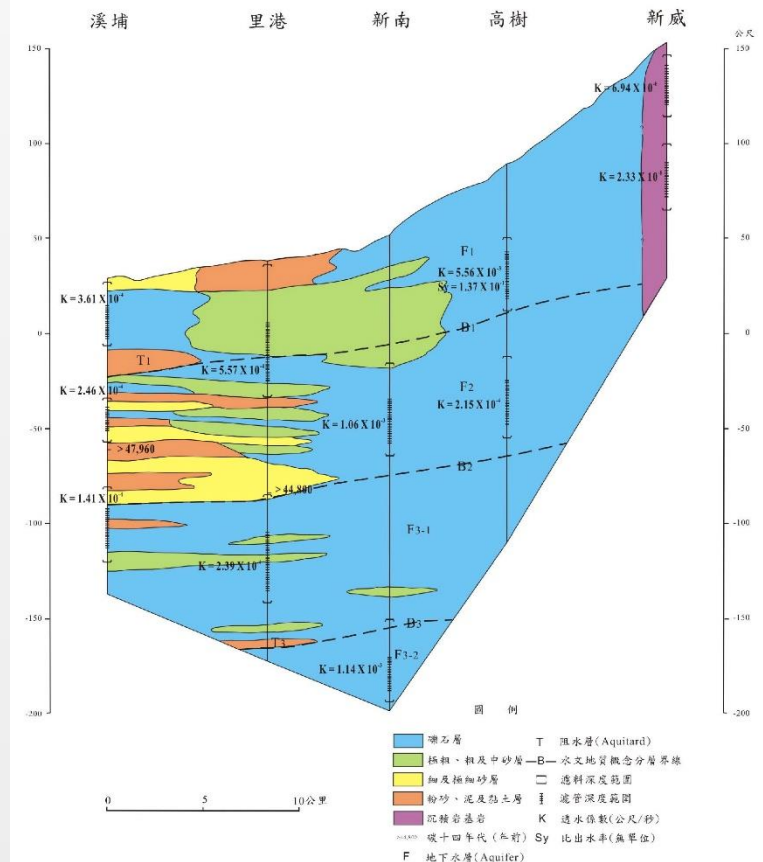


(Profile from Central Geological Survey)



# Geological Profile \_Pingtung Plain

- Coarse to middle grain sand is the major deposition, with some gravel and fine sand. The aquifer is a rich aquifer



(Profile from Central Geological Survey)



# Groundwater reserves and resources in Taiwan

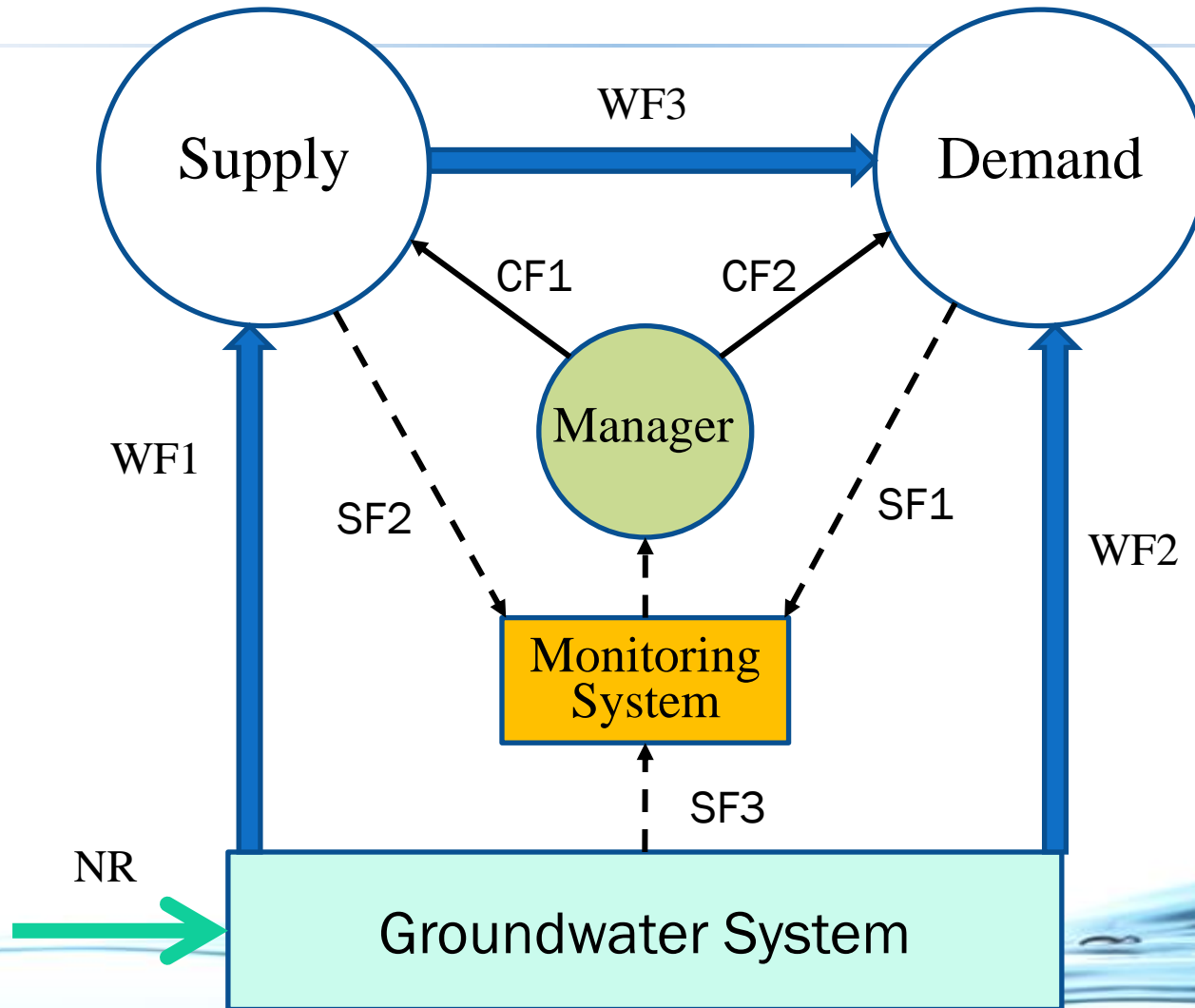
Groundwater Basin	Aquifer Thickness	Groundwater Reserves	Major Recharge Area (Unconfined Aquifer)	Groundwater Resources
Taipei Basin	Thick	High	Small	Low
Taoyuan Terrace	Thin	Low	Small	Low
Hsinchu and Miaoli area	Thin	Low	Small	Low
Taichung Basin	Thick	High	Large	High
Choushui Alluvial Fan	Thick	High	Large	High
Chianan Plain	Thin	Low	Small	Low
Pintung Plain	Thick	High	Large	High
East Rift Valley	Thick	High	Large	High
Lanyang Plain	Thick	High	Large	High

# RELATION FRAMEWORK OF GROUNDWATER MANAGEMENT

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# Relation Framework of Groundwater Management







# Relation Framework of Groundwater management

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- Supply : Water resources agency, Water supply company, Irrigation agency (previous water conservancy association)
- Demand (User) : Domestic, Industry, Agriculture
- Groundwater System : The aquifer system supplying groundwater
- WF1 : Groundwater pumping by water supplier
- WF2 : Groundwater pumping by water user (Demand)
- WF3 : Water supply from supplier to user





# Relation Framework of Groundwater management

- Monitoring System : System collecting all the signal from the demand (SF1), supply(SF2) and groundwater system (SF3)
- SF1 : Groundwater pumping signal from user
- SF2 : Groundwater pumping signal from water supplier
- SF3: Groundwater level signal from monitoring network and groundwater recharge from monitoring stations
- Manager : Water Resources Agency, Water Resources Department from local government
- CF1 : Management action (practice) to user (WRI, GCZ)
- CF2 : Management action to supplier (WRI, GCZ)
- NF: Nature Recharge

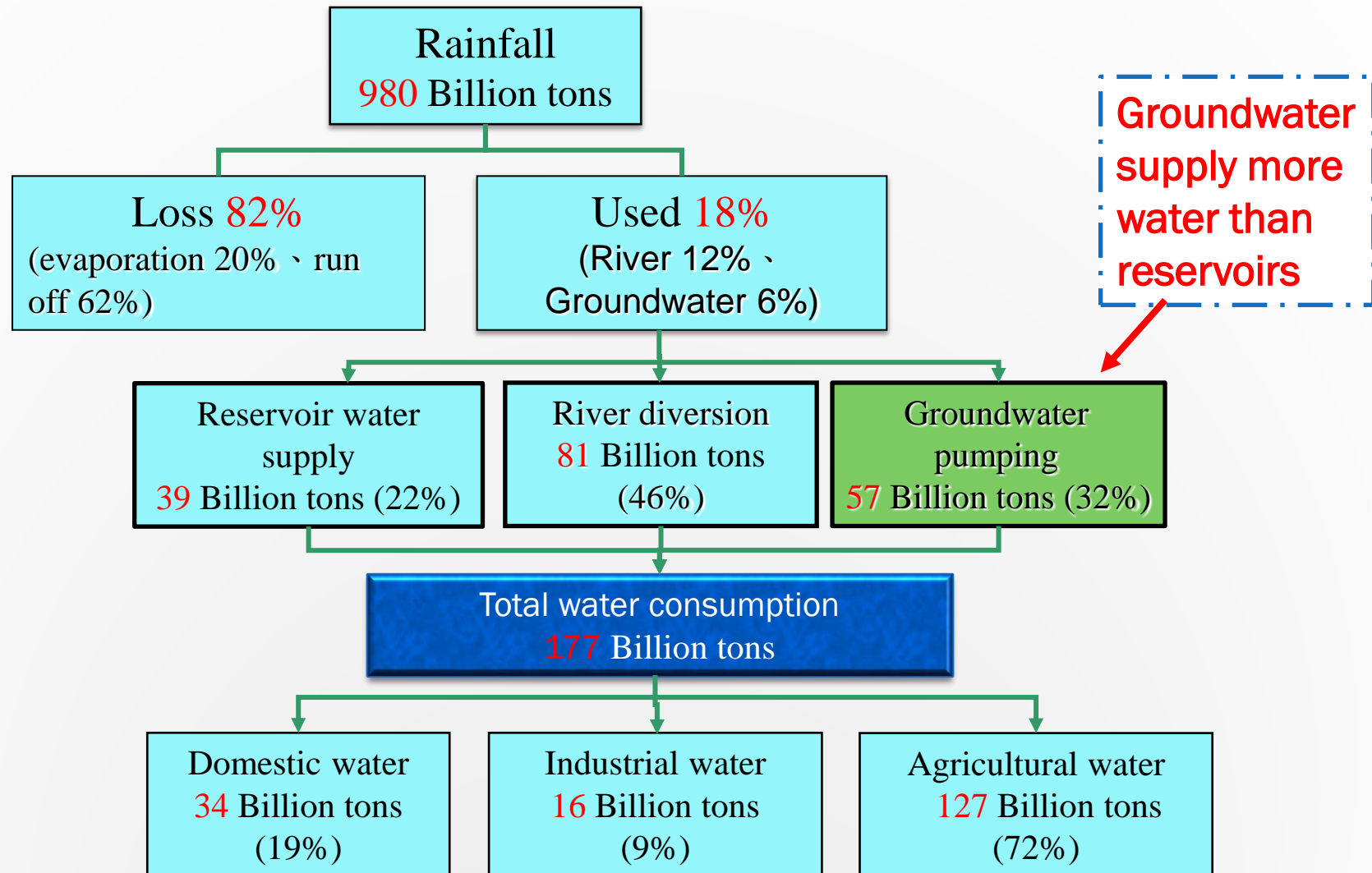


# THE GROUNDWATER MANAGEMENT PRACTICES IN TAIWAN

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(WHAT HAVE WE DONE IN THE PRESENT AND PAST)

# Demand and Supply of Water Resources in Taiwan



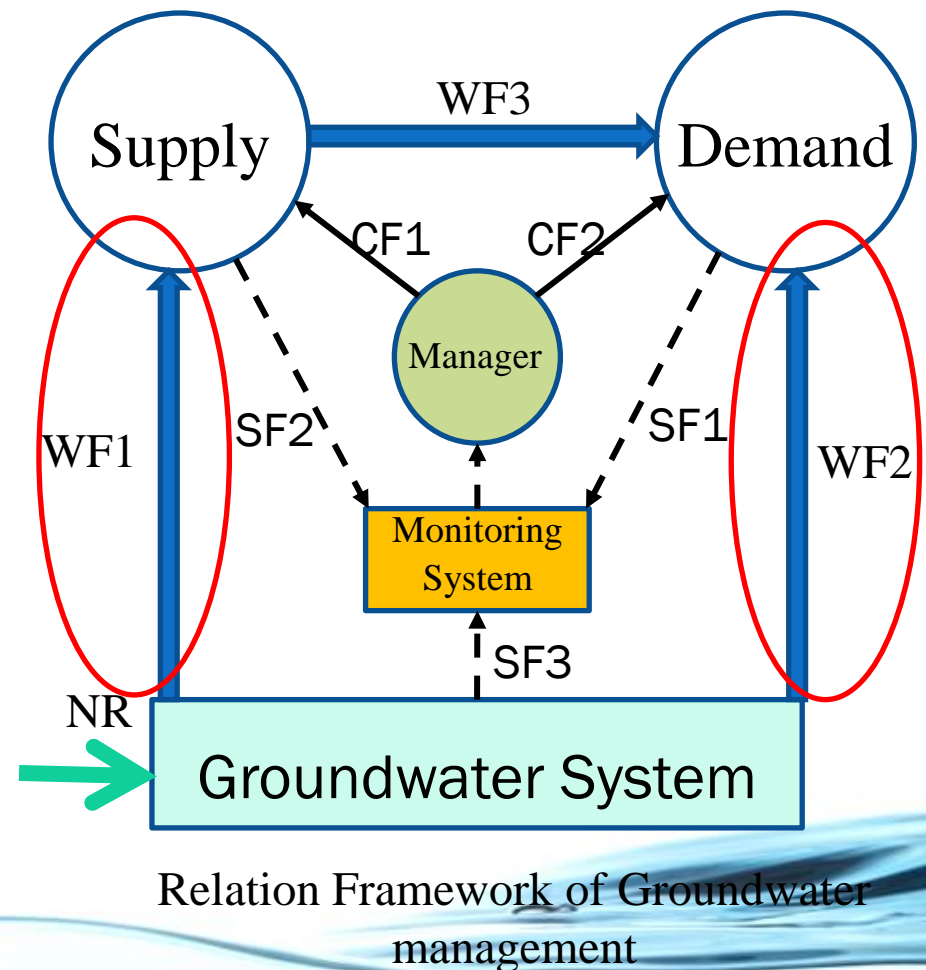
(Average value from 2006~2015, adapted from Water Resources Agency)





# Groundwater Development

- Large amount of groundwater pumped by the groundwater user directly without pumping information (no meters)
- The Water Supply Company and Water Resources Department also pumped groundwater.
- The Water Resources Agency have develop 2,000,000 CMD of Hyporheic zone water (groundwater near the river bed).



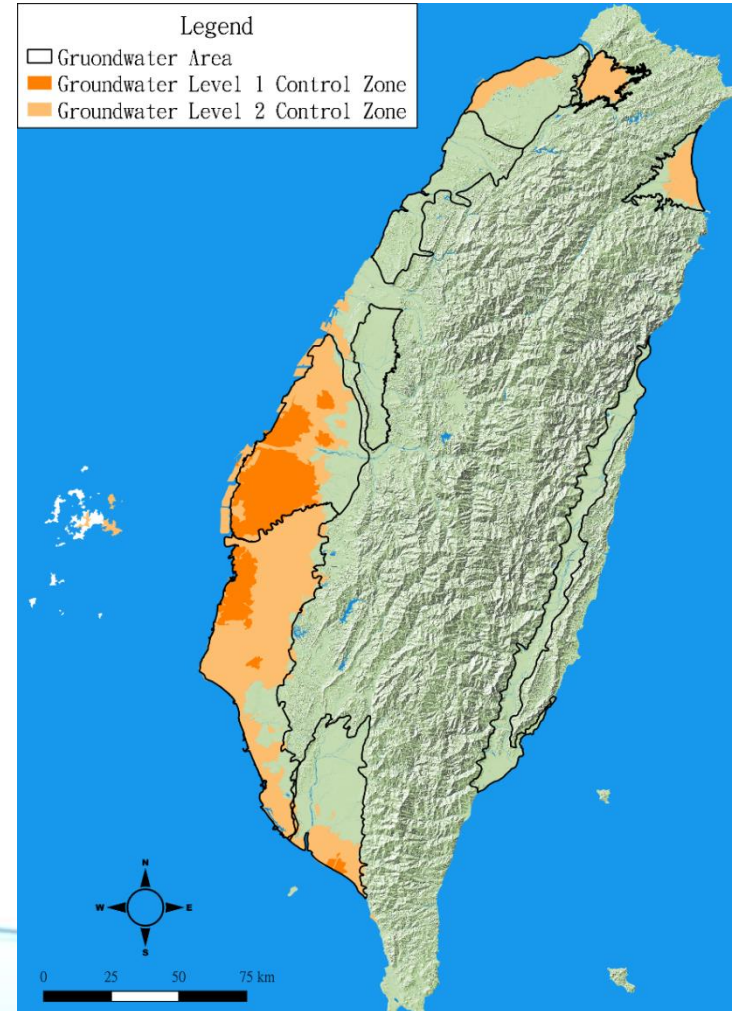
# Groundwater over pumping in the past

- Large amount of pumping water for the fishery along the **costal area (wrong locations)** without proper management
- Lacking the hydrogeological data of the aquifer system (in the past)
- **No information of the pumping (no meters)**
- Large groundwater drawdown caused land subsidence in the area,

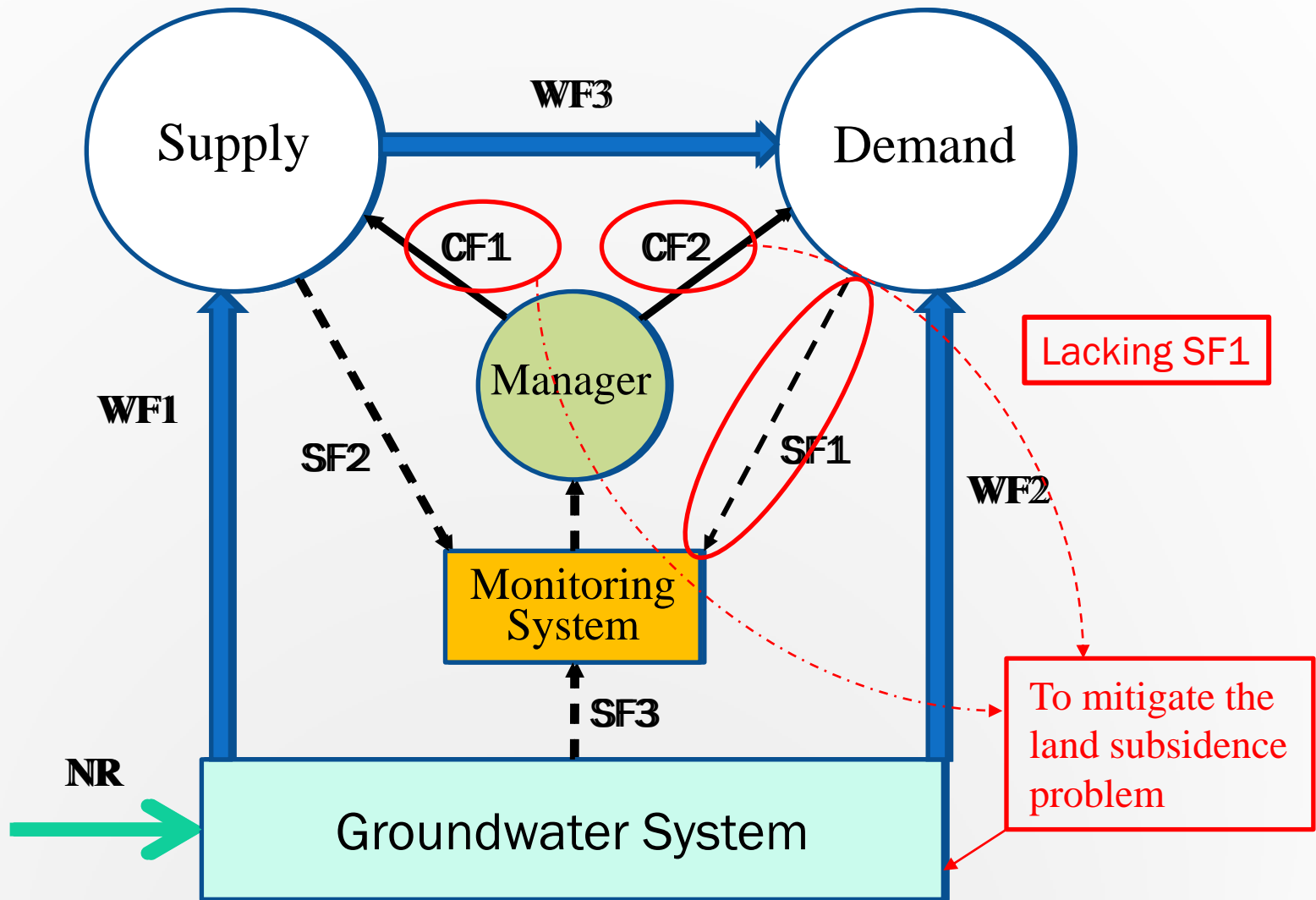


# Groundwater Control Zone

- The government authority had announced the **Groundwater Control Zone (GCZ)** by water law to **restrict or prohibit** the groundwater use to mitigate the land subsidence problem.
- The delineation of GCZ considered the factors of **land subsidence**, **groundwater level variation** and **geological conditions**, and should be updated every **five years**.



# Goal of Groundwater Control Zone

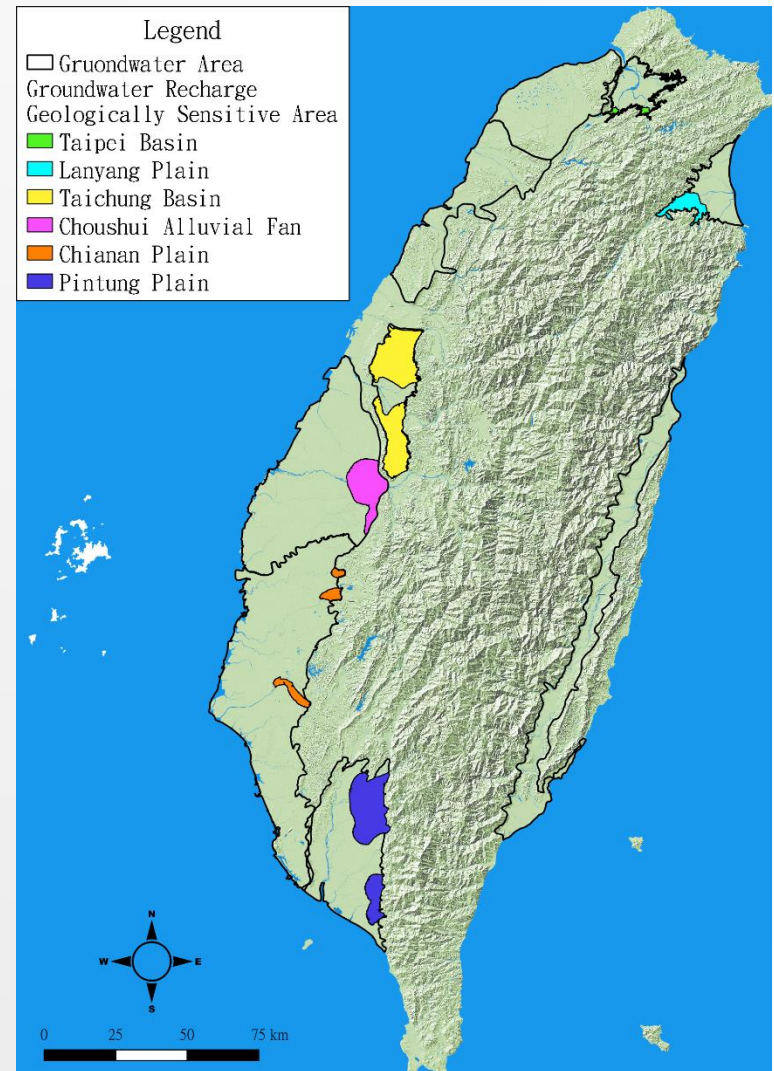


Relation Framework of Groundwater management

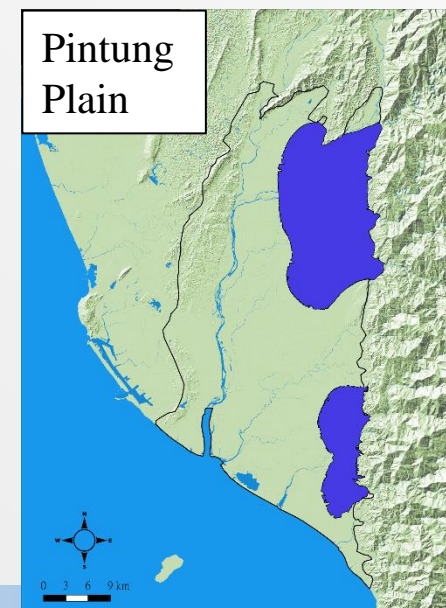
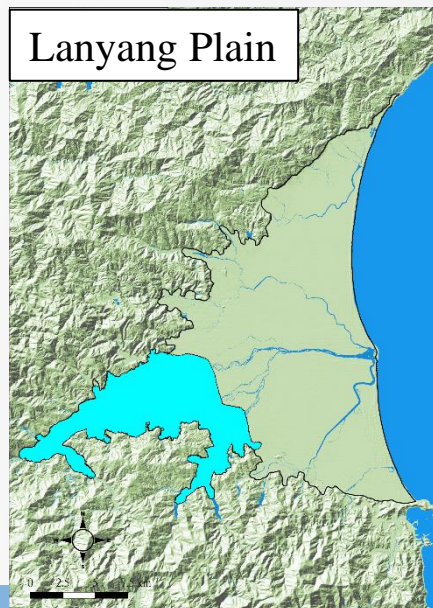
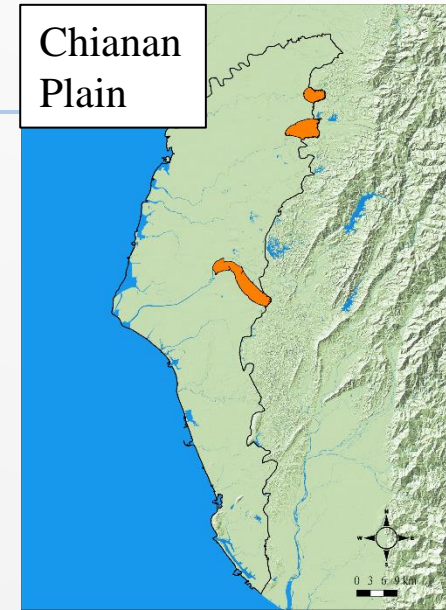
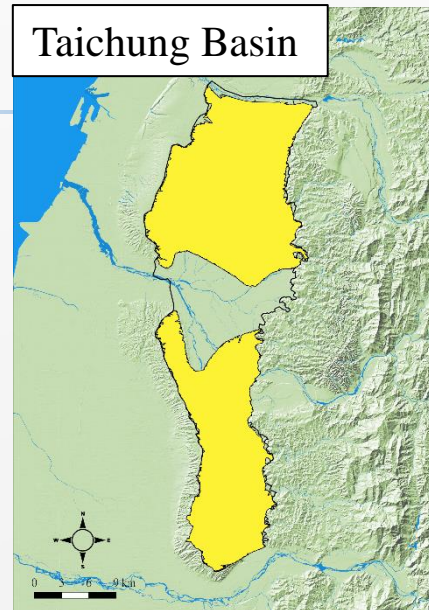
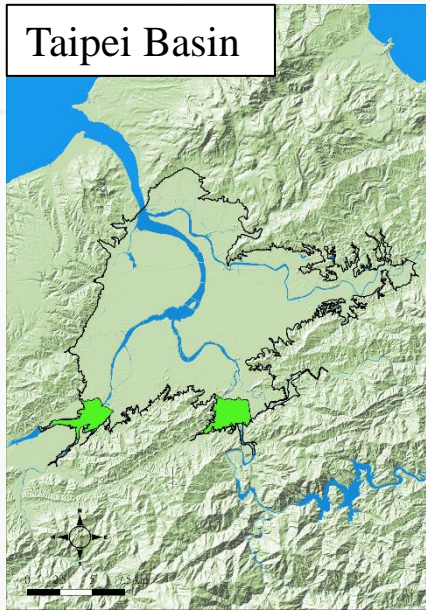


# Delineation of the Geologically Sensitive Area (GSA) for groundwater recharge (1/2)

- The geology law announcing in 2010 required the government authority to delineate **the Geologically Sensitive Area (GSA) for groundwater recharge** to enhance the **groundwater conservation** in Taiwan.
- The GSA of groundwater recharge are: 1. Groundwater recharge area for all major regional aquifers, and 2. Important groundwater resources of regional water supply.
- The GSA for groundwater recharge have delineated and announced for **six major groundwater basins**.

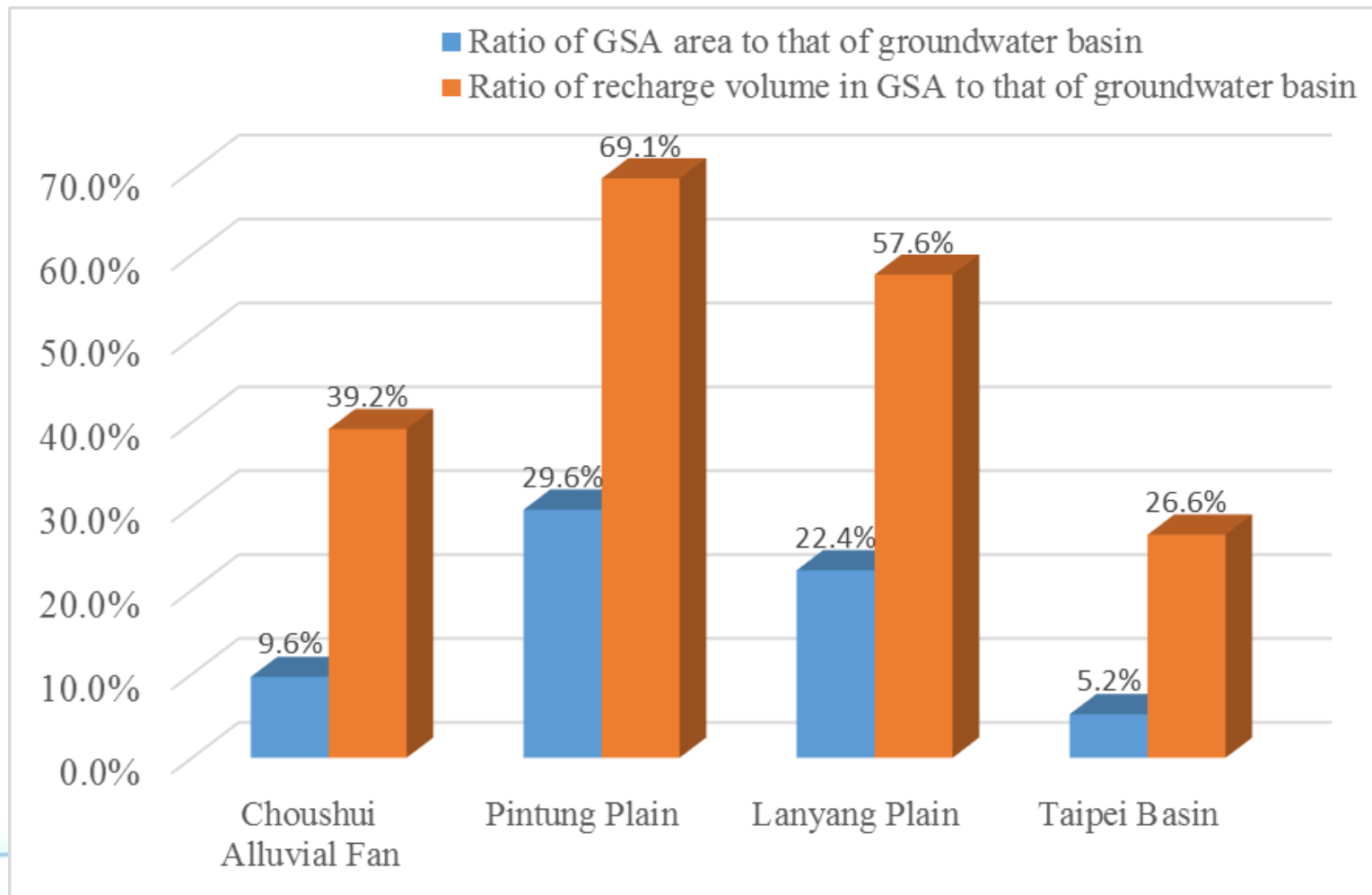


# Delineation of the Geologically Sensitive Area (GSA) for groundwater recharge (2/2)





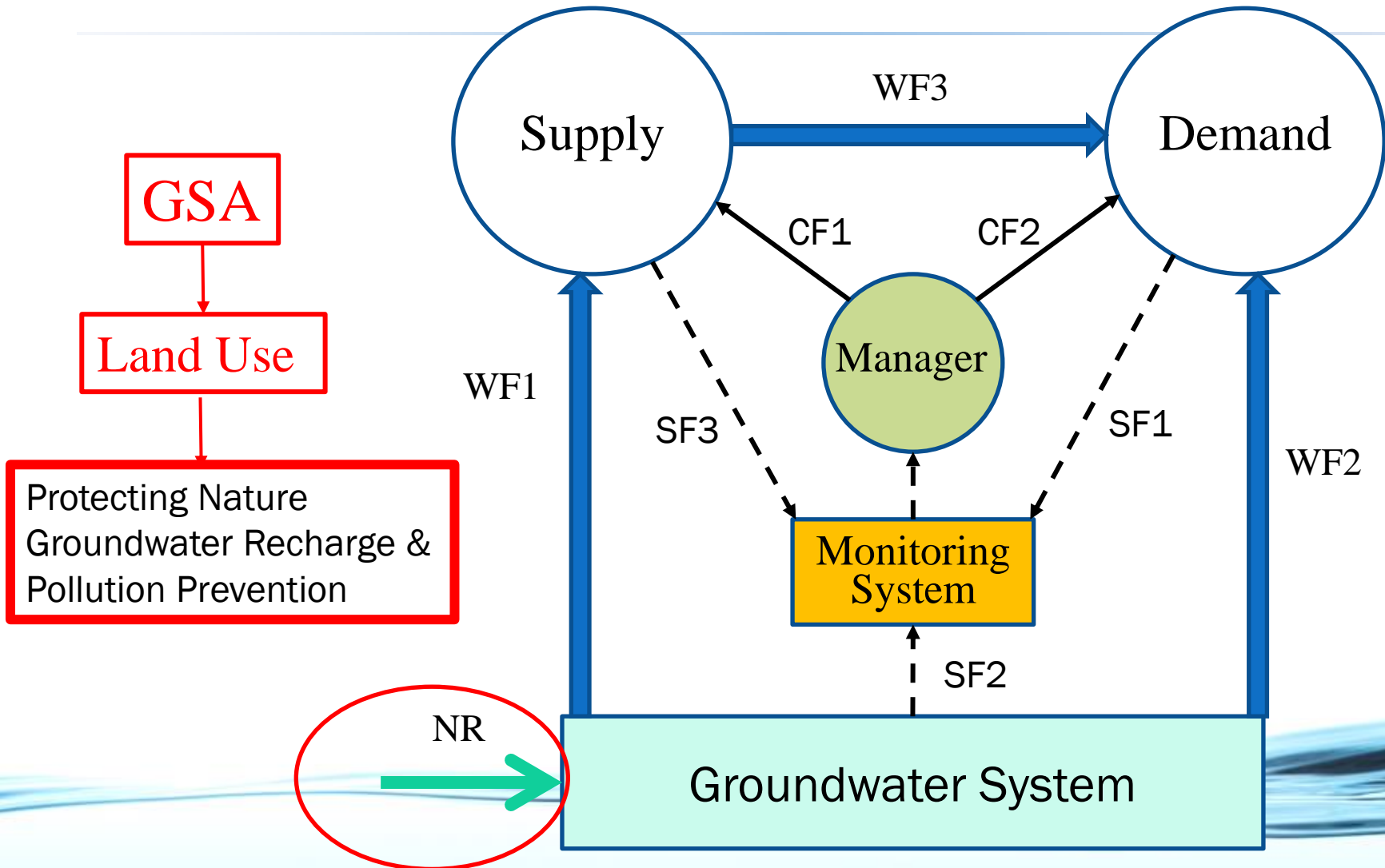
# Impact assessments of the GSA for groundwater recharge







# Goal of Delineating the GSA for recharge

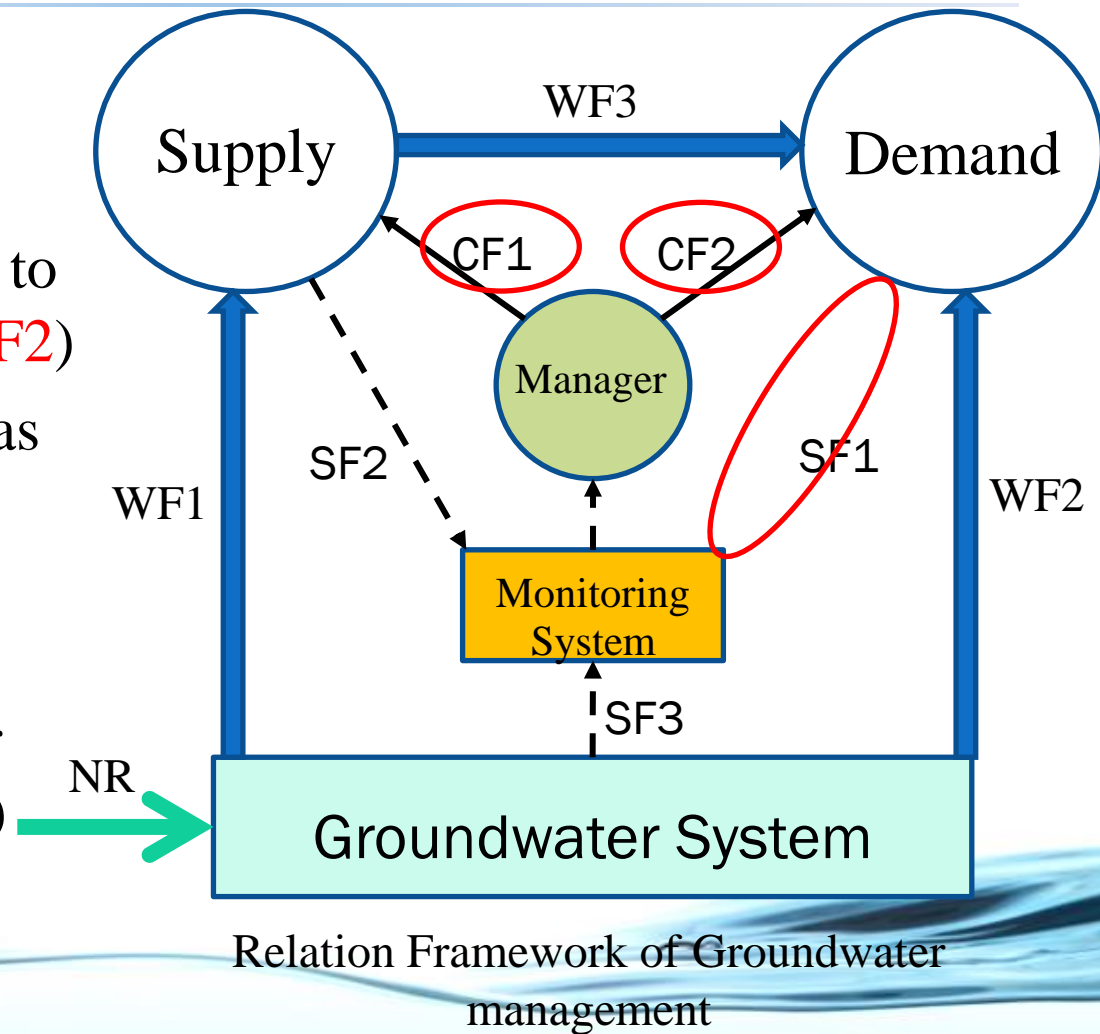


Relation Framework of Groundwater management



# Groundwater Rights Issuance

- The only management action (practice) that the **local government** can enforce management rules to user and supplier (**CF1, CF2**)
- **The central government** has no direct management action
- Lacking the pumping information from the User (SF1). The issuance (CF2) has no scientific basis.
- More on demand side



# GROUNDWATER MANAGEMENT STRATEGIES IN TAIWAN

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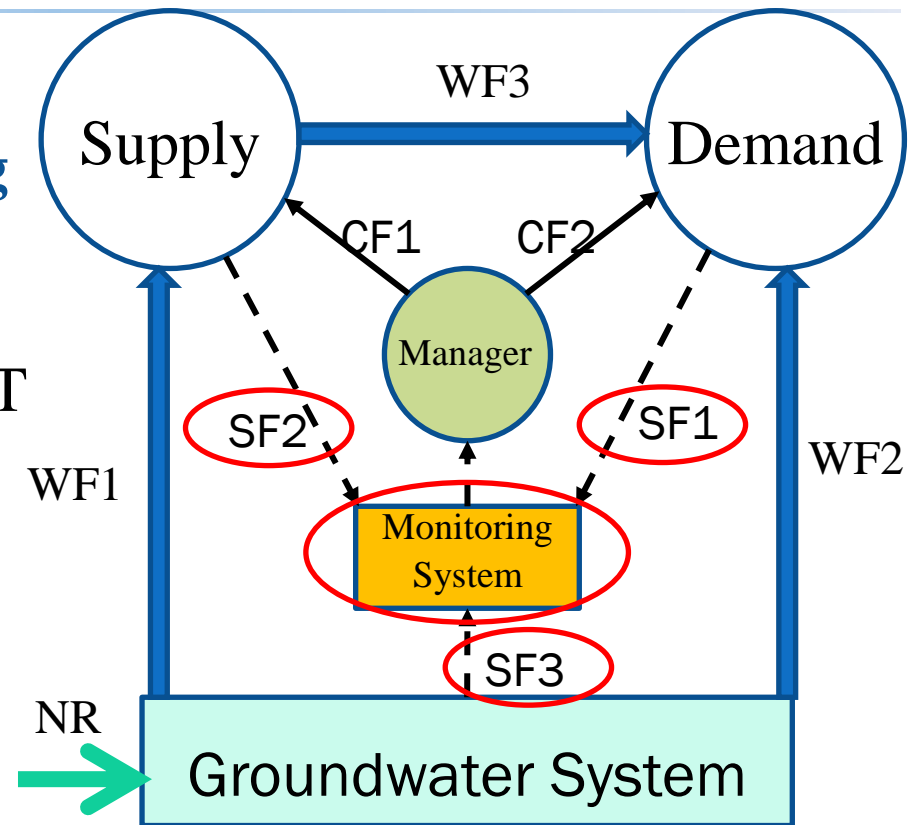
(WHAT CAN WE DO IN THE FUTURE)



# Short-Term Strategies

- **Strategy 1 : Monitoring System Enhancing**

- Enhancing the Groundwater monitoring network by advanced IOT Technology (on going) (SF3)
- Groundwater **recharge monitoring** and assessment (New) (SF3)
- Water meter installation (on going) (SF1 & SF2)

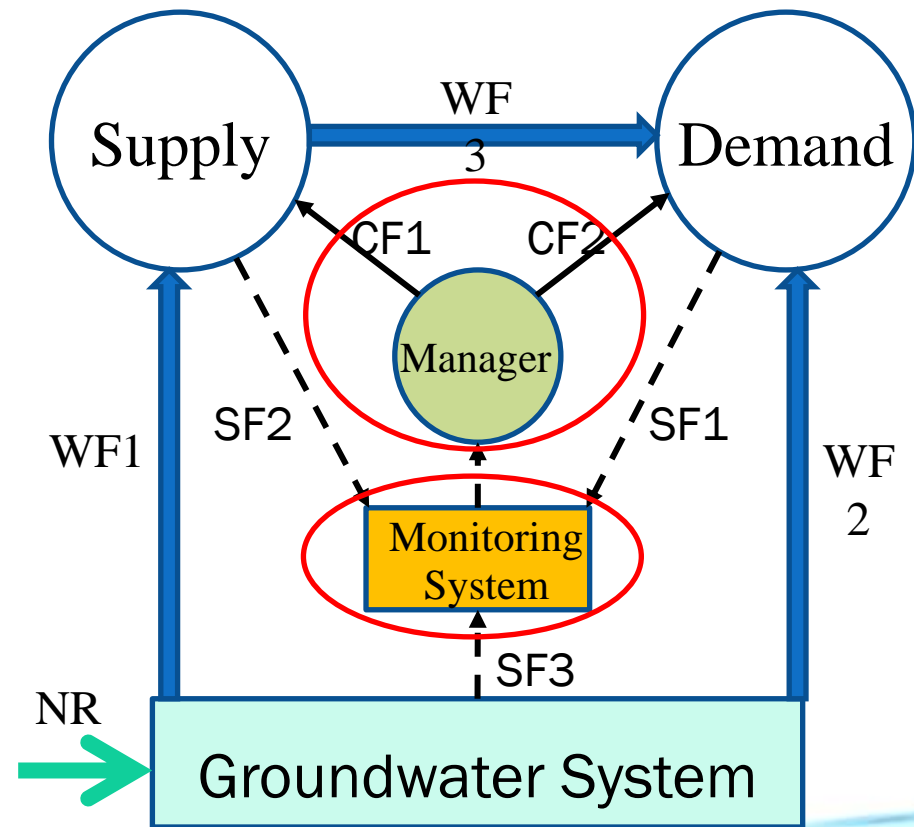


(Relation Framework of Groundwater management)



# Short-Term Strategies

- **Strategy 2 : Enhancing Groundwater Rights Issuance**
- Continuing the work of strategy1, we can issue the groundwater rights more effectively under a **rolling basis**

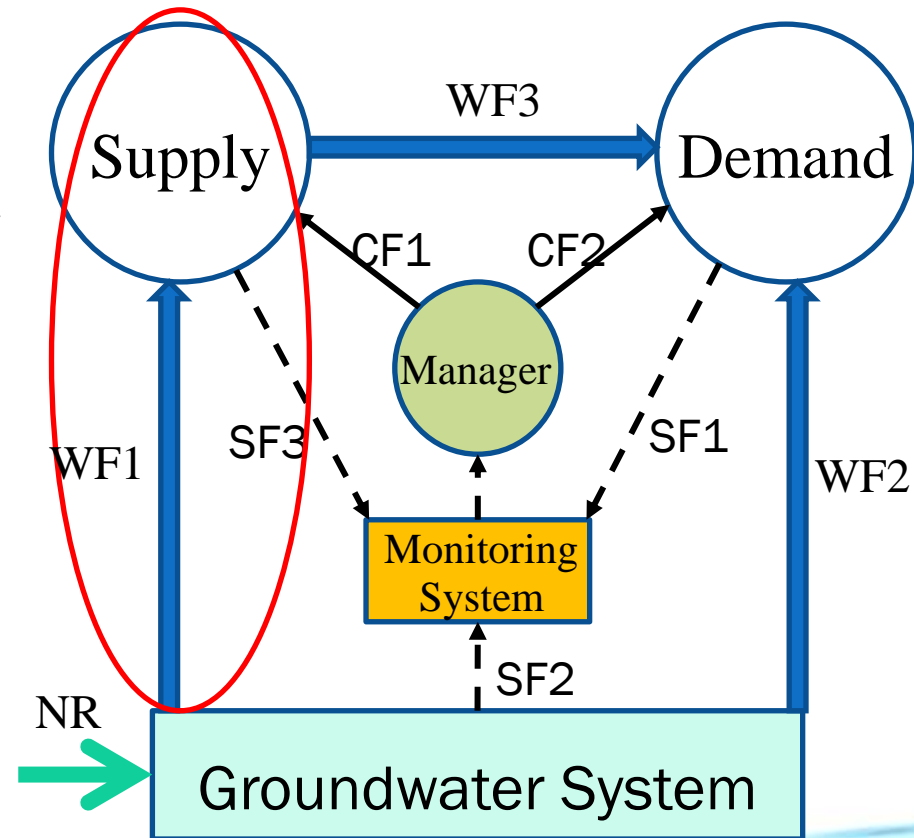


Relation Framework of Groundwater management



# Short-Term Strategies

- **Strategy 3 : Development of Emergency Well System (Supply management)**
  - 180 emergency wells with 370000 CMD were developed in the extreme drought event and significantly mitigate the shortage impact.
  - Continuing the emergency pumping wells system planning and development
  - Pumping wells are suitable for emergency use because of low maintenance cost
  - The emergency system capacity can not the count into the regular system capacity
  - The emergency system is to **reduce the shortage risk** instead of **increasing the overall system capacity**



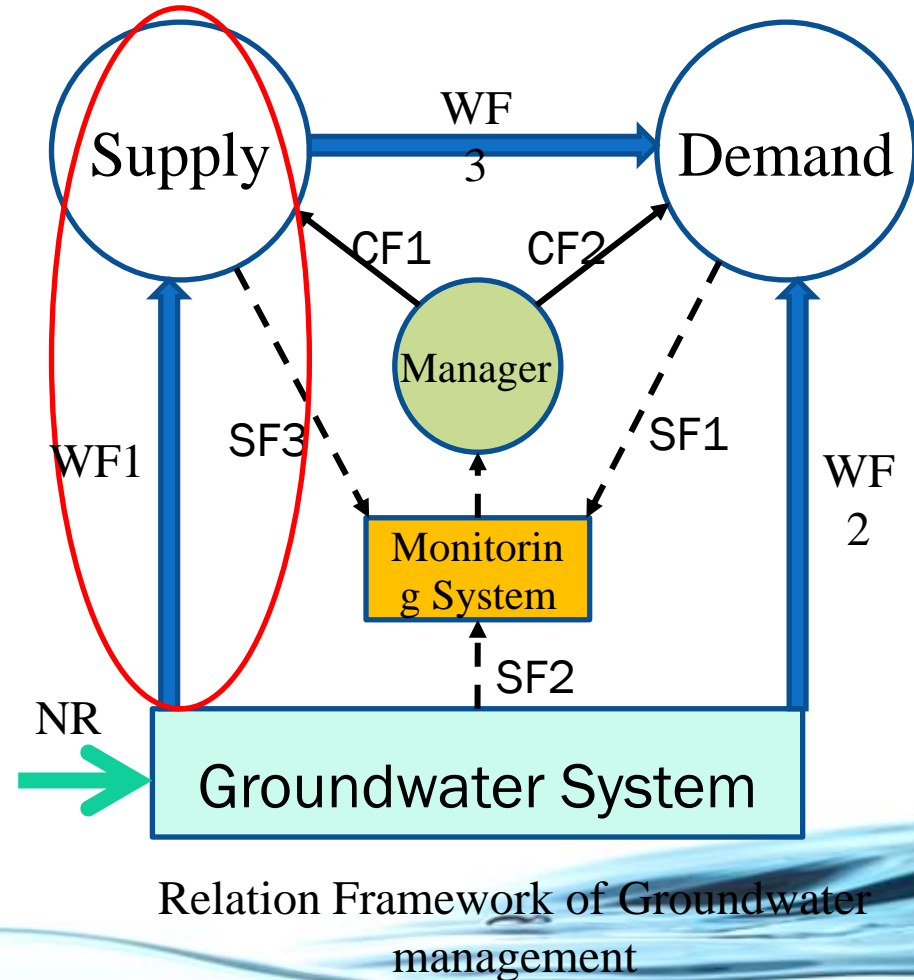
Relation Framework of Groundwater management





# Long-Term Strategies

- **Strategy 4 : Development of Conjunctive Use System for Regular Groundwater Supply (Supply Management)**
  - Groundwater supply as a regular basis and is counted into the overall system capacity
  - Should conjunctive operate with surface water system.
  - The recharge can be nature or artificial. For nature recharge, the system may pump groundwater in dry season with shorter time-period and recharge system by nature in wet season with longer time-period





# Long-Term Strategies

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- **Collecting the groundwater use fee**
  - To enhance groundwater management, changing the people attitudes on groundwater use is more importance than financial consideration.
  - Only recognizing the groundwater as **resources** is not enough. People should realize the groundwater is a **valuable resources**.
  - Free is the most expansive



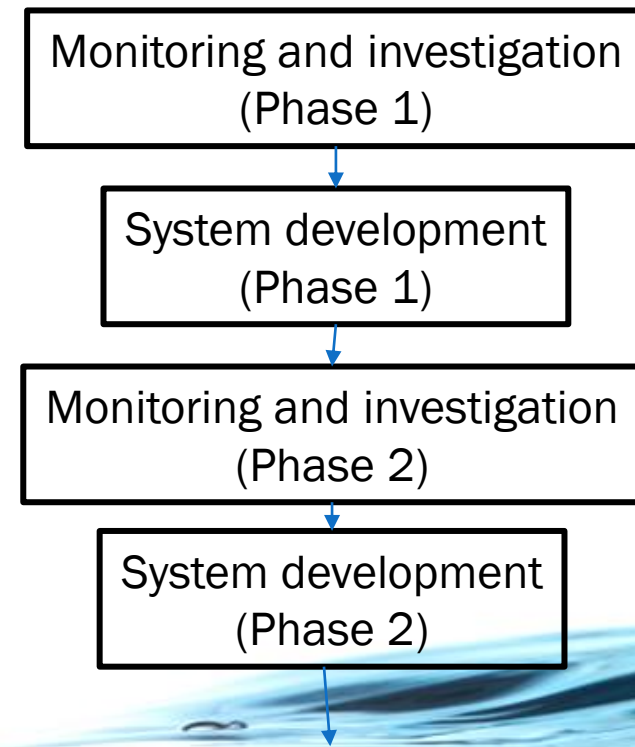
# Management principles beyond the strategies

- **Location dependence**

The amount of pumping that causes subsidence in one place may be a safe yield in other place

- **Rolling basis development**

- Due to the geological heterogeneous the uncertainty of groundwater analysis are higher than that of surface system in general.
- To reduce the analysis uncertainty achieving an acceptable level as the surface water is unrealistic in the phase 1 step.
- The uncertainty can only be reduced to an acceptable level through the rolling basis development from management perspective.
- A monitoring system is the basis for rolling development.



(Rolling basis process)



# Conclusions

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- Taiwan has rich groundwater resources and deserves more attention and investment to enhance the management.
- Monitoring system including meter installation is fundamental infrastructure for the Groundwater Rights Issuance and rolling basis development.
- Groundwater is suitable as an emergent water source that should not be counted as a regular water system capacity.
- Groundwater system development should be rolling basis to reduce the uncertainty and increase efficiency.
- **Groundwater use fee** is the most effective management practice in the long run.





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Thank you for your attention!

