Integrated hydrological Analysis platform
for flood prevention design and
water resource development

Kwan Tun LEE

Dean of Engineering College
Distinguished Professor of River & Harbor Engineering
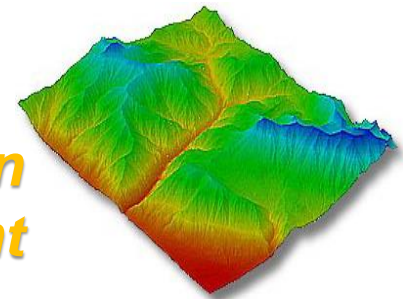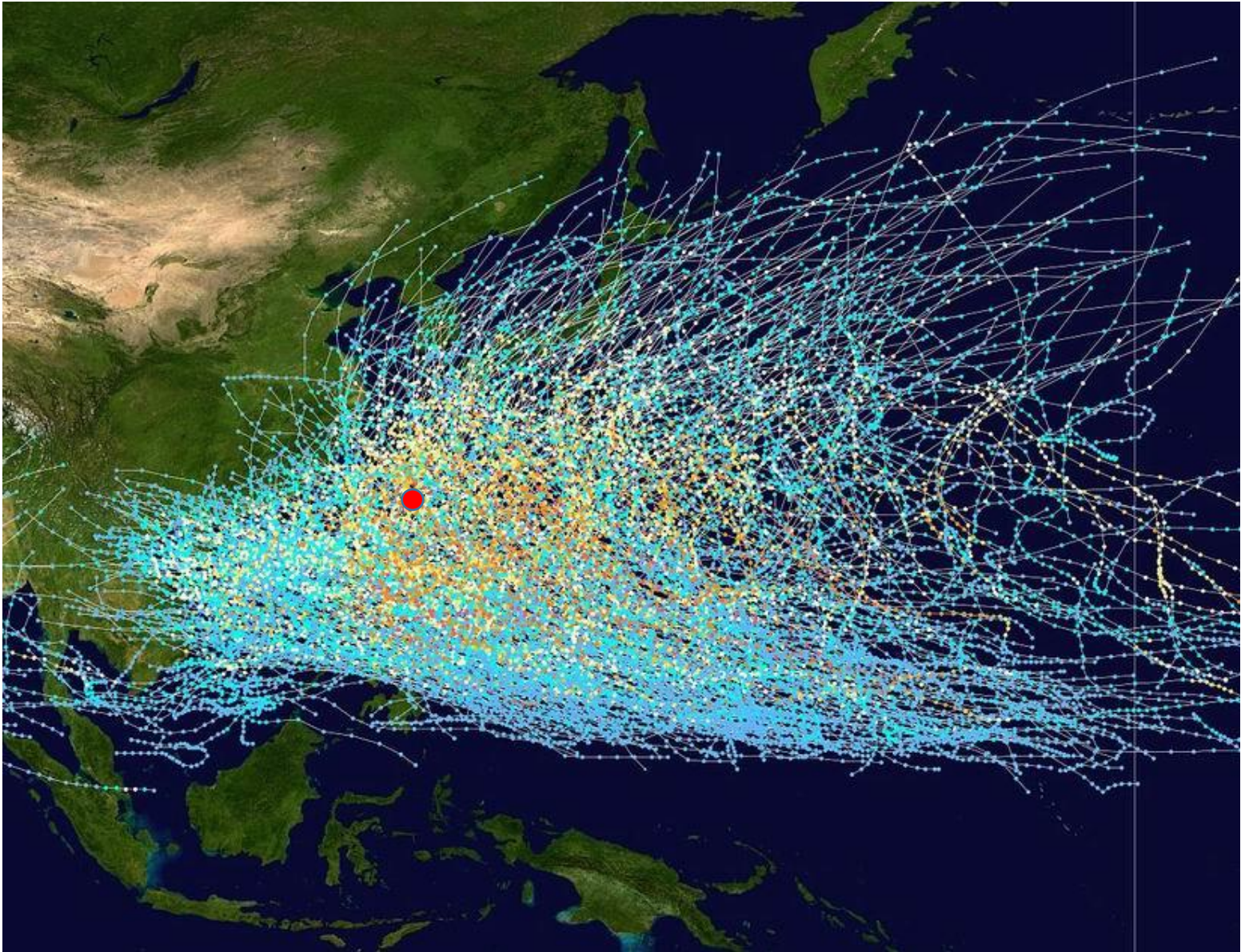**National Taiwan Ocean University, Keelung, Taiwan.**

Outline

- **Background**

- **Platform for flood prevention design**

- **Platform for water resource development**

- **Platform system and database**

- **Summary**

Flood Prevention Design
Water Resource Development

Pacific typhoon tracks

https://commons.wikimedia.org/wiki/File:Pacific_typhoon_tracks_1980-2005.jpg

Disaster prevention works

Hillside drainage

Check dam

Levee

Diversion channel

Dam & Reservoir

Urban storm sewer

A basin-based platform integrating
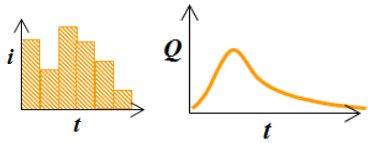hydrology, hydraulics, water resource planning,
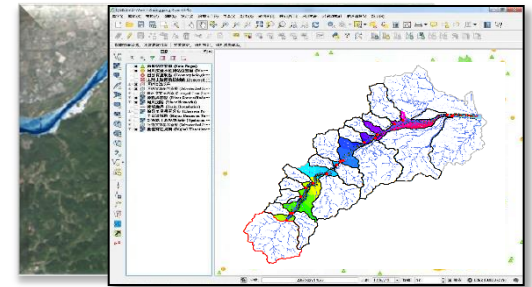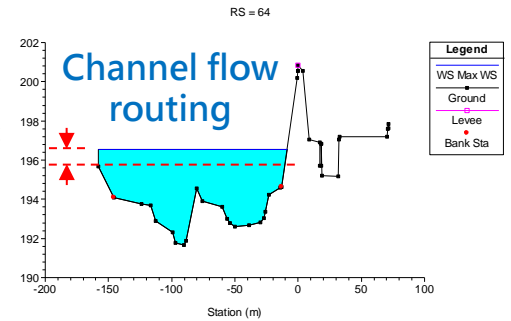and database system is required.

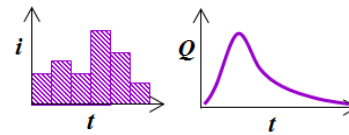# Processing of hydrological analysis

Platform for Flood Prevention Design

Platform for flood prevention design
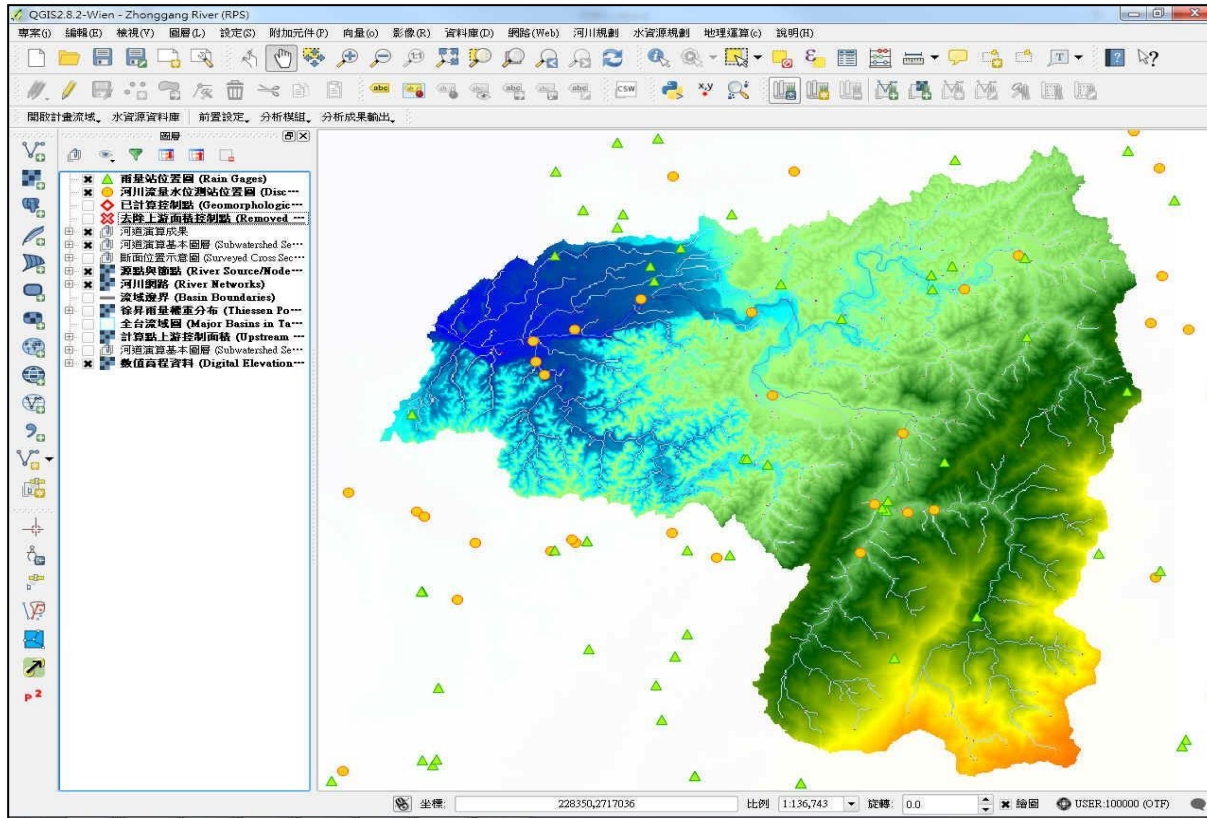
Watershed Geo.

Rainfall Freq. Anal.

Spatial Rainfall Anal.

Watershed Runoff Routing

Channel Flow Routing

Storm Event Sim.

Design Discharge Q_T

Flood Inundation Sim.

Urban Flood Sim.

Ministry of Science and Technology, Taiwan
Council of Agriculture, Taiwan
Water Resource Agency, Taiwan

Platform for flood prevention design

Watershed Geo.

Rainfall Freq. Anal.

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Urban Flood Sim.

Geomorphologic factors for subwatersheds and lateral flow areas

Ministry of

Council of Agriculture, Taiwan

Water Resource Agency, Taiwan

Platform for flood prevention design

Watershed Geo.

Rainfall Freq. Anal.

Spatial Rainfall Anal.

Watershed Runoff Routing

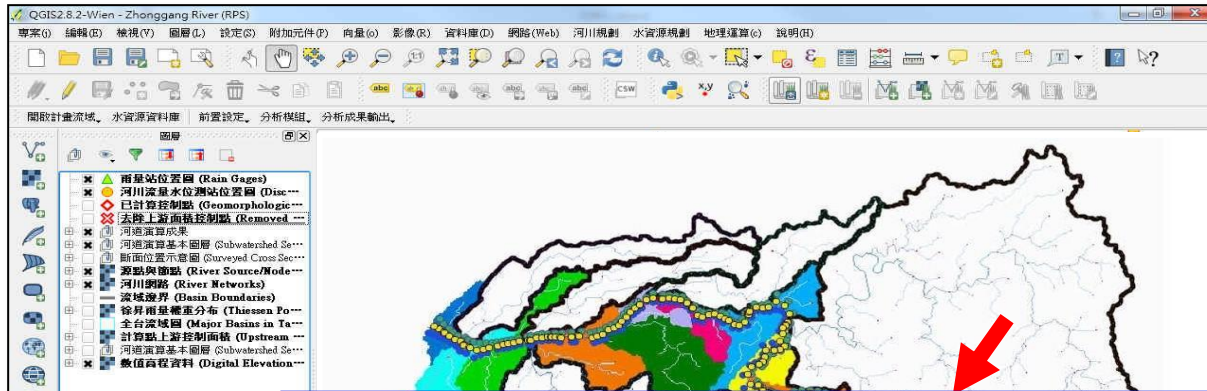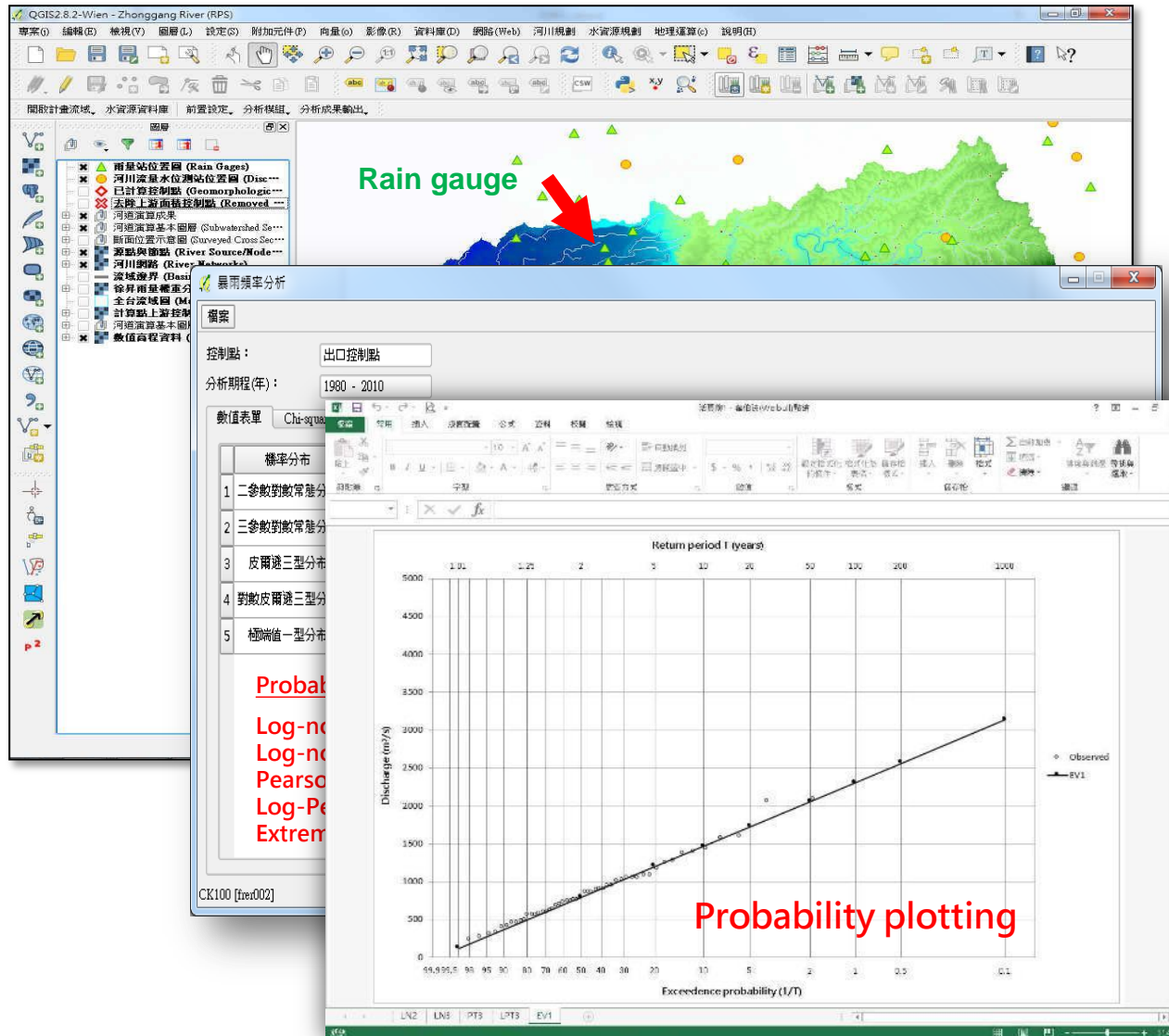**Channel Flow Routing**

Storm Event Sim.

Design Discharge Q_T

Flood Inundation sim.

Urban Flood Sim.

Platform for flood prevention design

Watershed Geo.

Rainfall Freq. Anal.

Spatial Rainfall Anal.

Watershed Runoff Routing

Channel Flow Routing

Storm Event Sim.

Design Discharge Q_T

Flood Inundation Sim.

Urban Flood Sim.

Thiessen method   **Isohyetal method**   **Kriging method**

Platform for flood prevention design

Watershed Geo.

Rainfall Freq. Anal.

Spatial Rainfall Anal.

Watershed Runoff Routing

Channel Flow Routing

Storm Event Sim.

Design Discharge Q_T

Flood Inundation Sim.

Urban Flood Sim.

KW-GIUH model
SCS triangular UH
Dimensionless UH
Nash model
Tank model

Rainfall-runoff simulation for gauged and ungauged watersheds

Platform for flood prevention design

Watershed Geo.

Rainfall Freq. Anal.

Spatial Rainfall Anal.

Watershed Runoff Routing

Channel Flow Routing
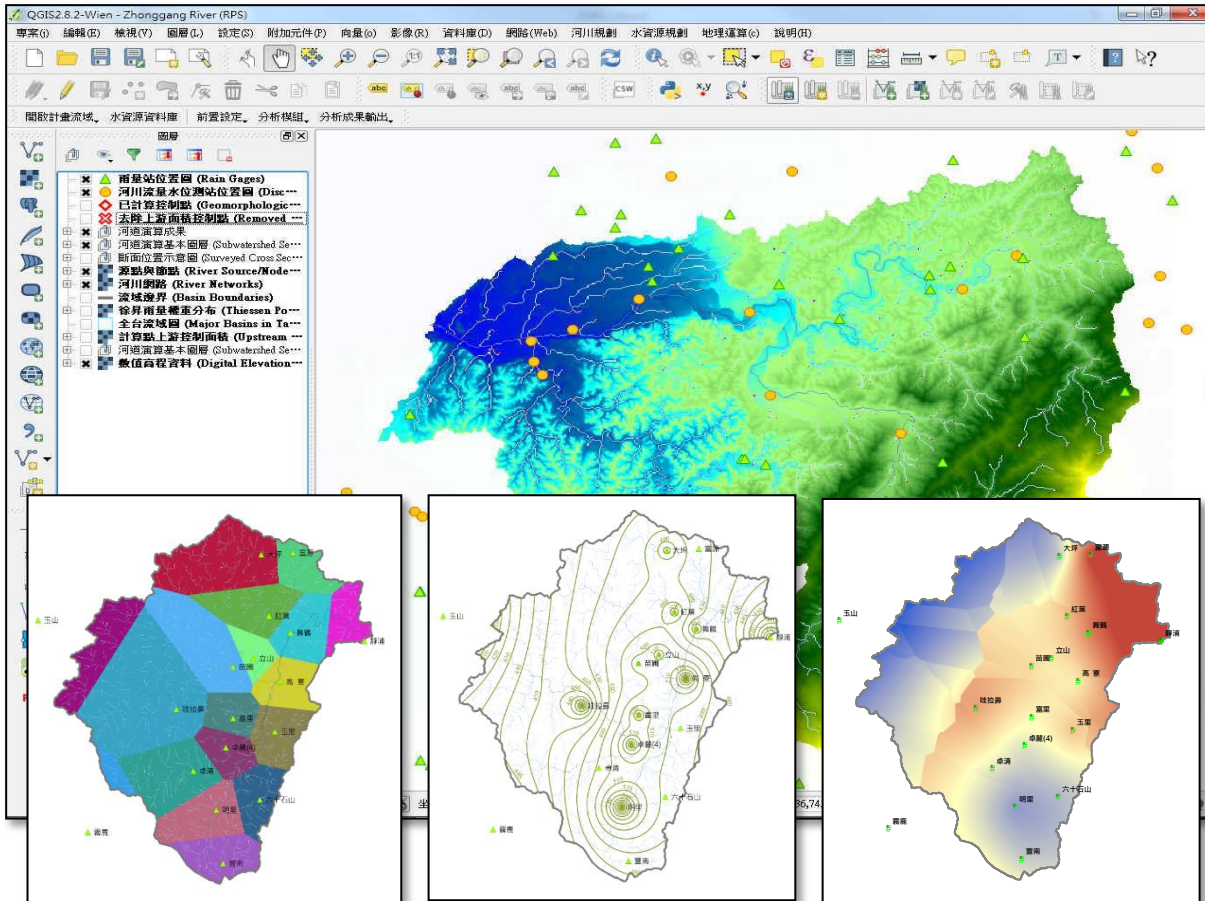
Storm Event Sim.
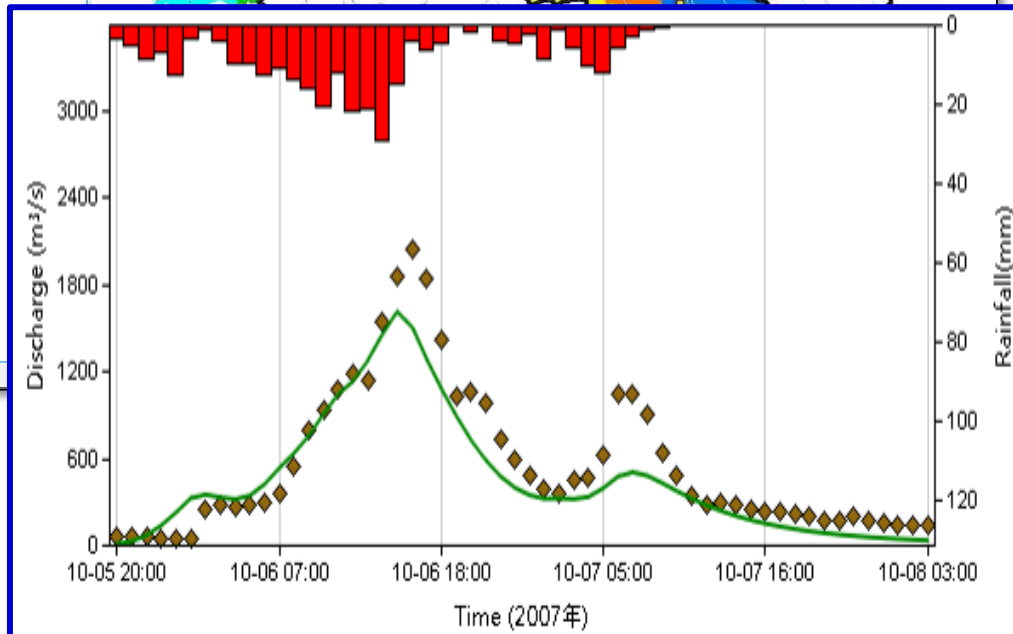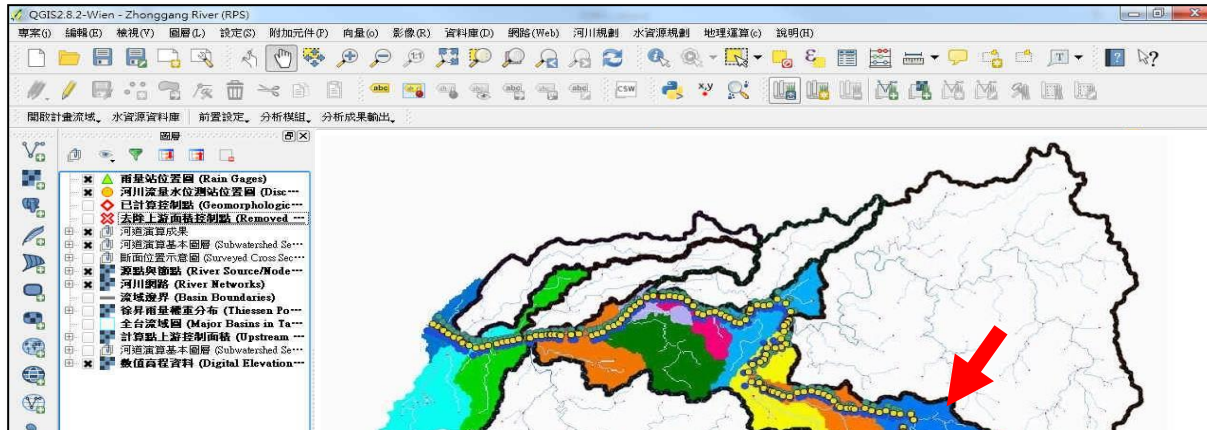
Design Discharge Q_T

Flood Inundation Sim.

Urban Flood Sim.

Dynamic-wave model
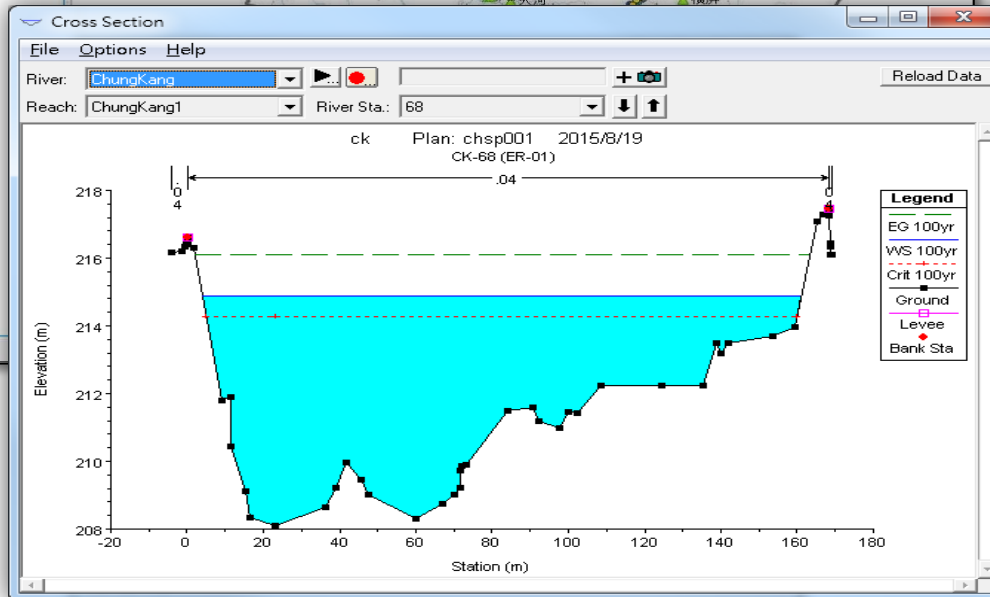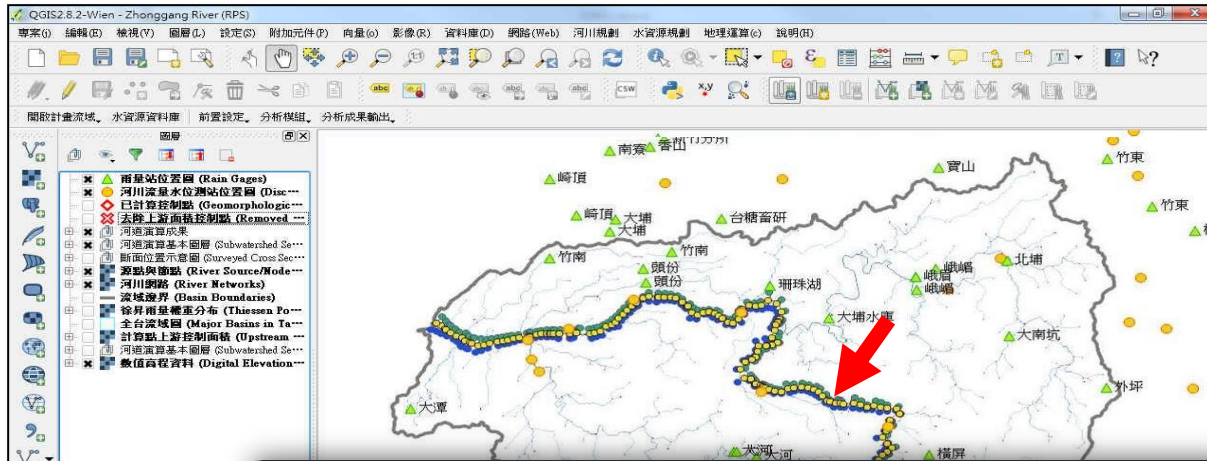Diffusion-wave model
Kinematic-wave model
Muskingum-Cunge model

Water stage estimation at a specified channel section

Platform for flood prevention design

HEC-RAS

3D water-stage profile along the main stream for a specified rainstorm

Watershed Geo.

Rainfall Freq. Anal.

Spatial Rainfall Anal.

Watershed Runoff Routing

Channel flow Routing

Storm Event Sim.

Design Discharge Q_T

Flood Inundation Sim.

Urban Flood Sim.

Integrate watershed runoff model & channel flow model

Platform for flood prevention design

200-yr design hyetograph

Watershed Geo.

Rainfall Freq. Anal.

Spatial Rainfall Anal.

Watershed Runoff Routing

Channel Flow Routing

Storm Event Sim.

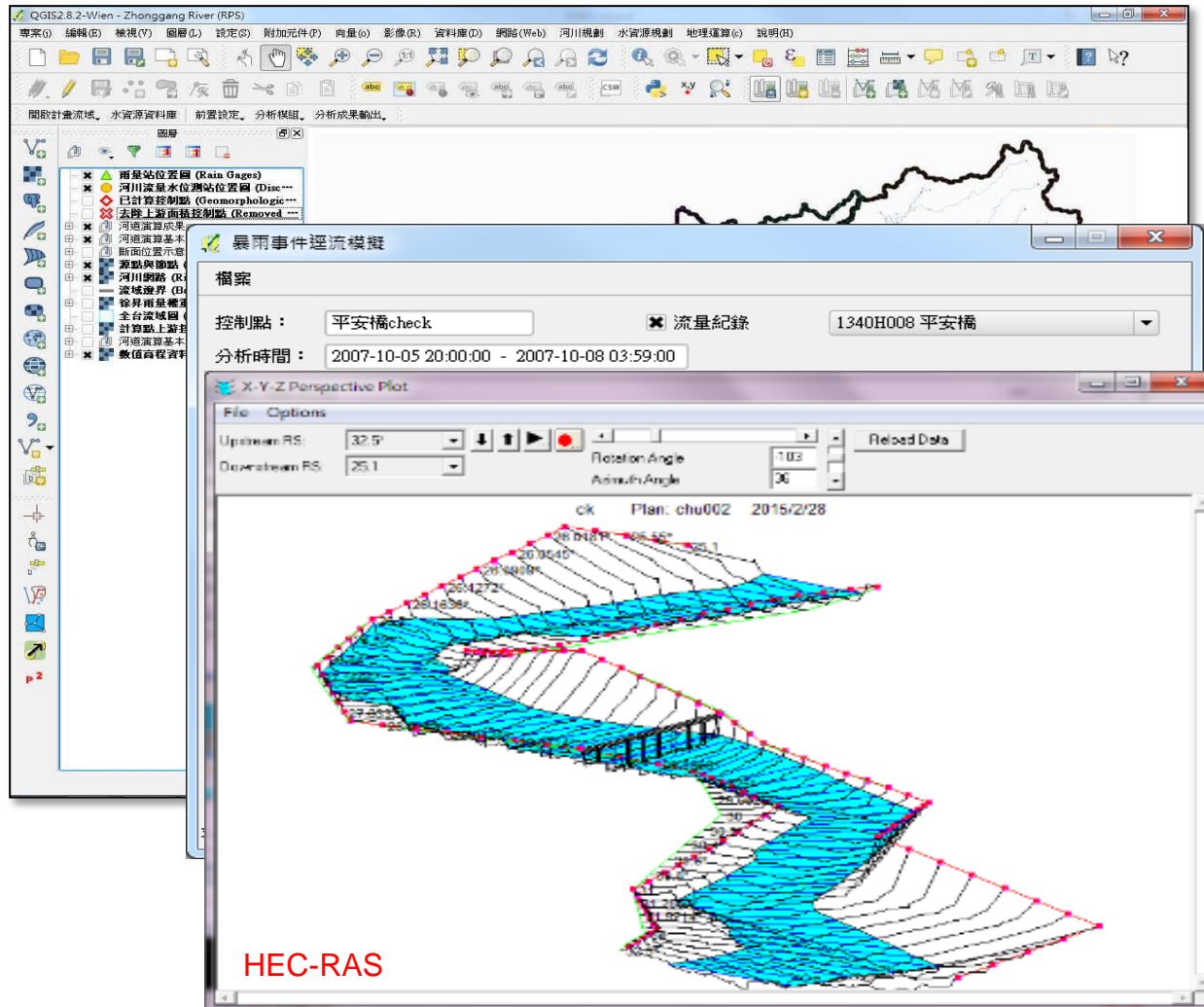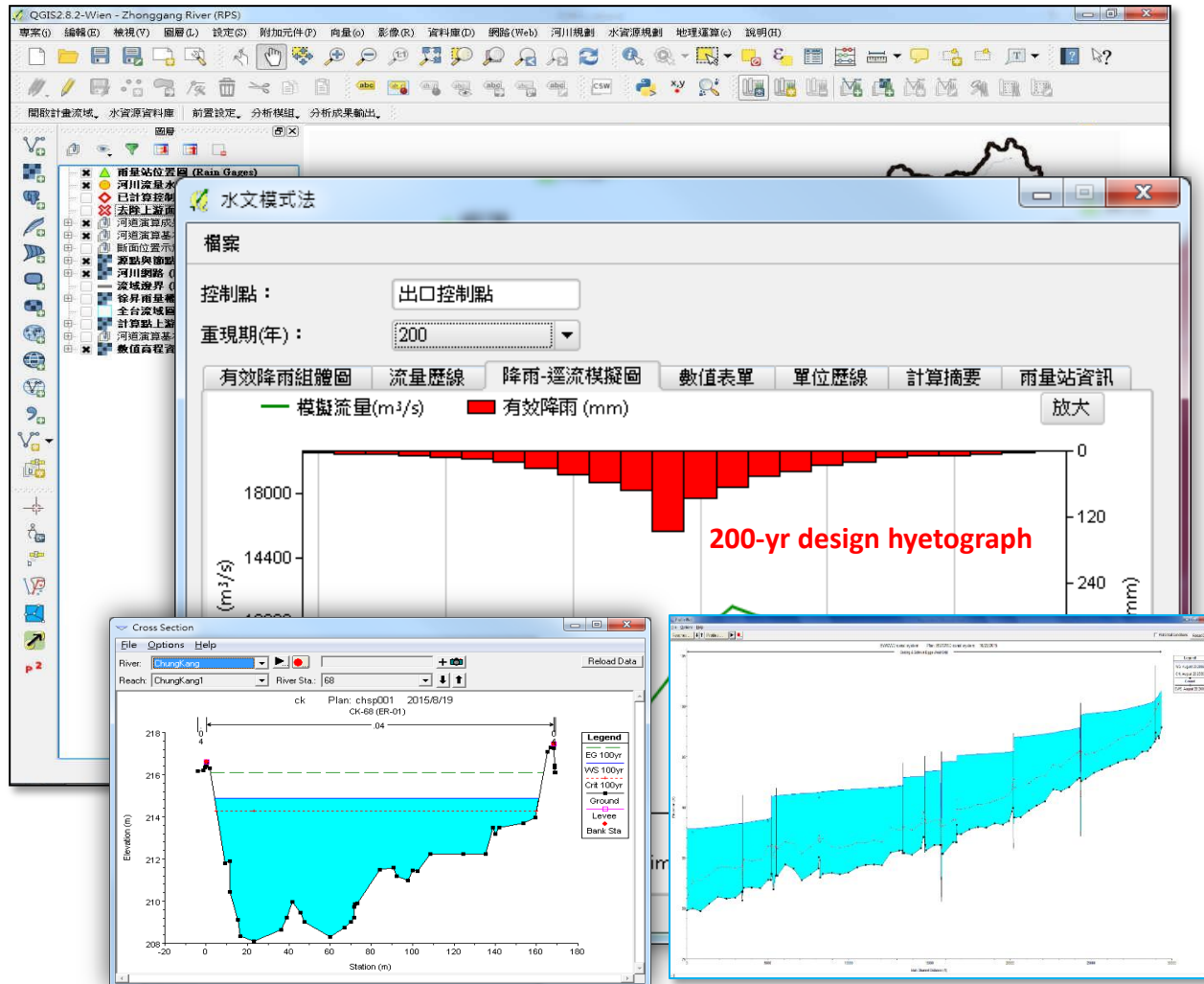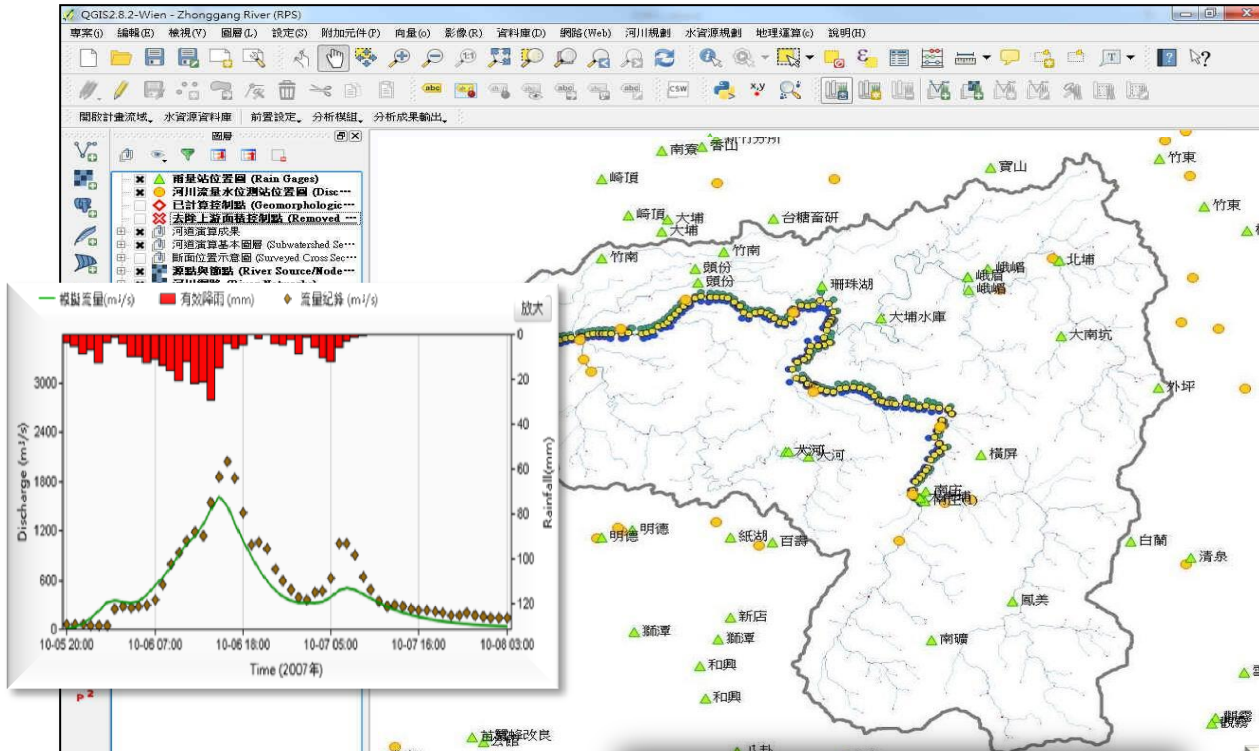**Design Discharge Q_T**

Flood Inundation Sim.

Urban Flood Sim.

Integrate
watershed runoff model &
channel flow model

Water stage profile along the main stream under a design return period condition

Platform for flood prevention design

Watershed Geo.
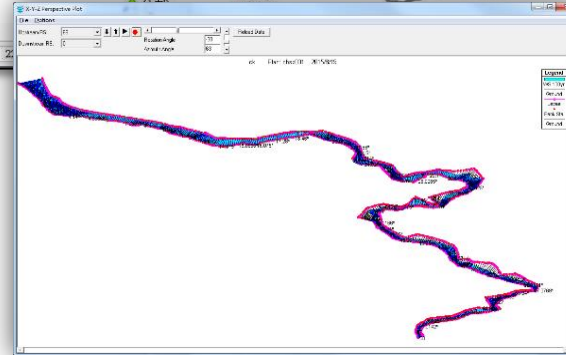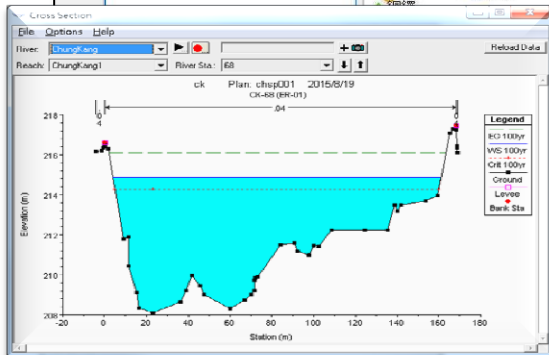
Rainfall Freq. Anal.

Spatial Rainfall Anal.

Watershed Runoff Routing

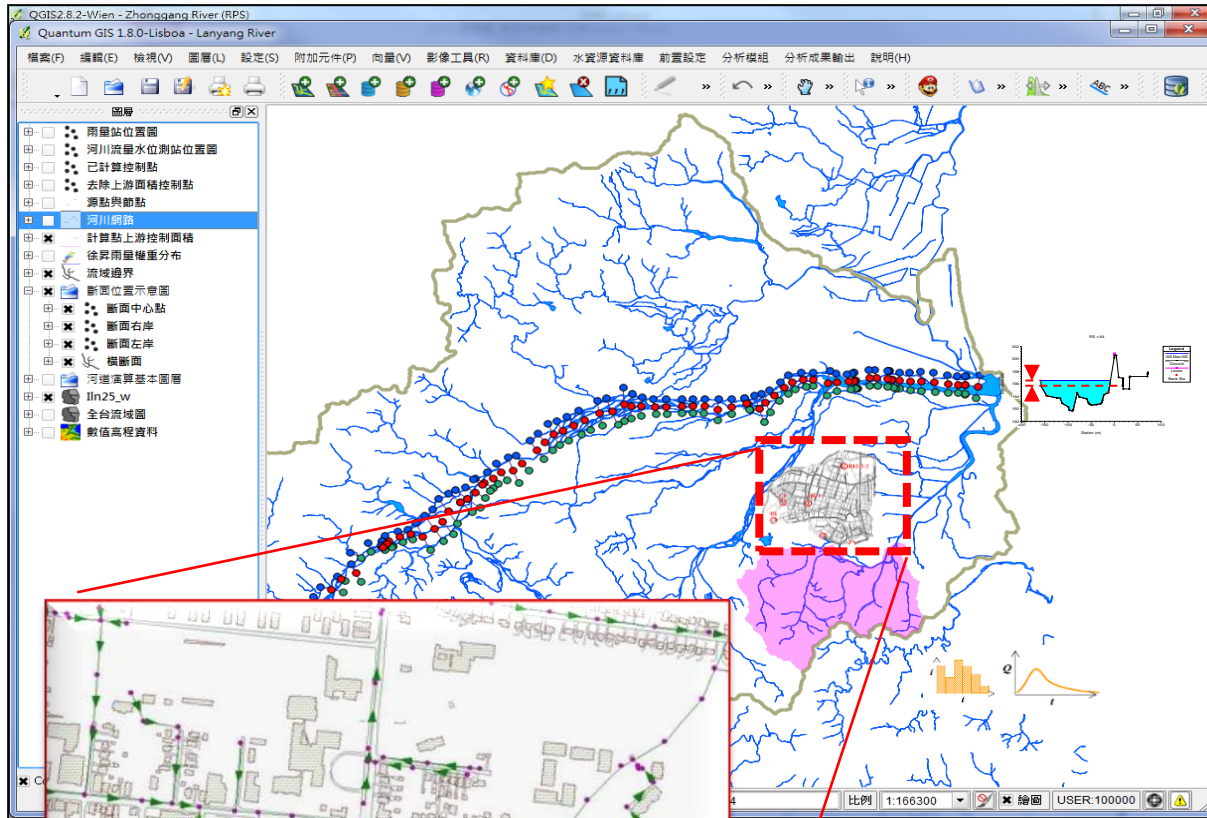**Channel Flow Routing**

Storm Event Sim.

Design Discharge Q_T

Flood Inundation Sim.

Platform for flood prevention design

Watershed Geo.

Rainfall Freq. Anal.

Spatial Rainfall Anal.

Watershed Runoff Routing

Channel Flow Routing

Storm Event Sim.

Design Discharge Q_T

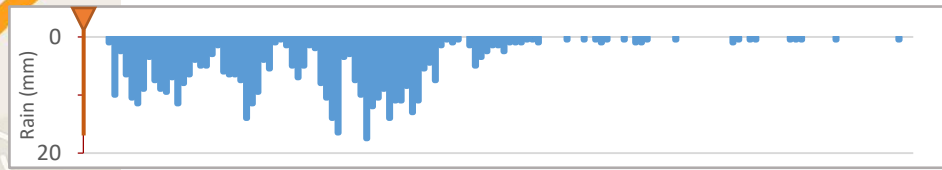**Flood Inundation Sim.**

Urban Flood Sim.

1. Developing the street/sewer network on SWMM
2. Extracting upstream/downstream boundary conditions from this platform
3. Routing SWMM model with the hydrological database

Urban street/sewer flow simulation

Combined urban drainage system

Street–Sewer drainage waterway

New Taipei City
2012/6/12 rainstorm

SWMM

Water Elevation Profile: Node 3234-319 - 3234-313

Ground surface

Road curb
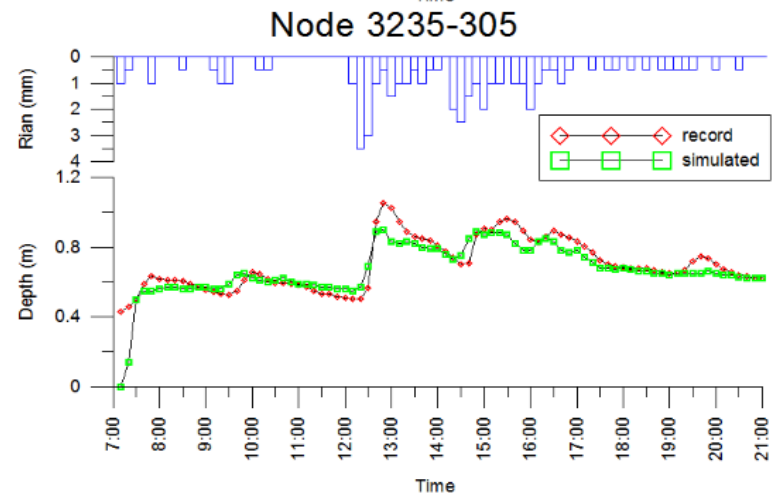
Street

Sewer crown

Sewer bottom
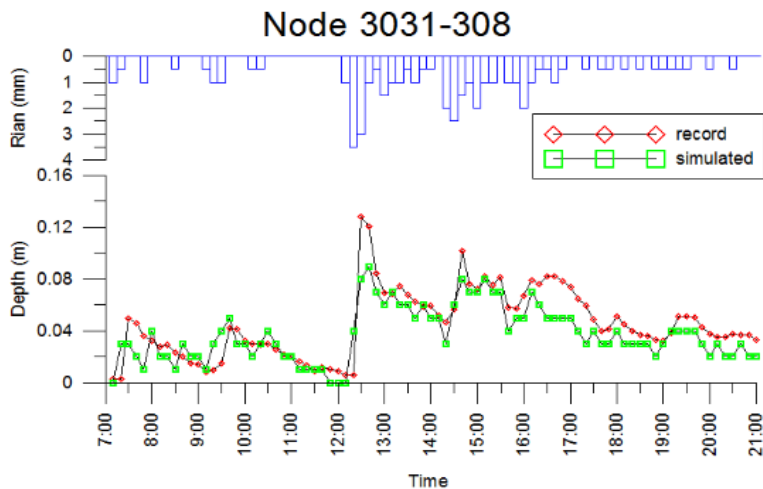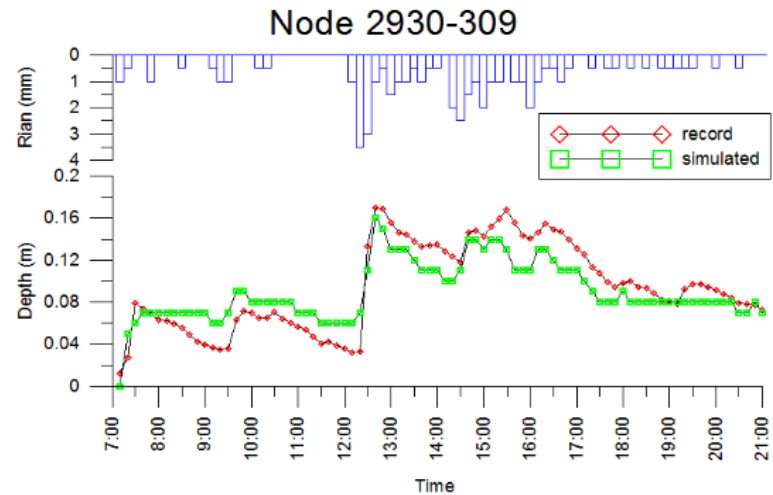
06/11/2012 22:00:00

17

Model verifications
- urban street/sewer flow routing model

sewerage   pressure type sensor

■ **New Taipei City 2015/03/23 rainstorm**
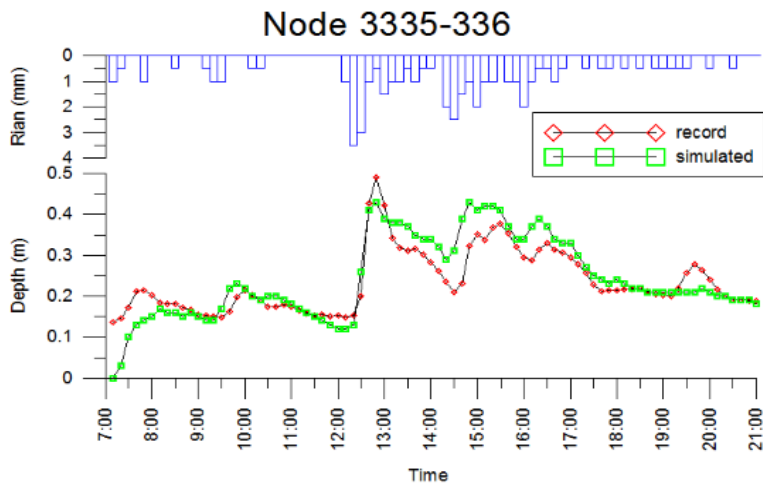
Platform for
Water Resource Development

Platform for water resource development

Reservoir characteristics curves

Reservoir Storage Anal.

Geologic Information

Probable Max. Flood

Daily Flow Simulation

Water Supply Anal.

Transbasin Diversion

Hillslope Analysis

Reservoir Life Anal.

Weather Working Days

Platform for water resource development

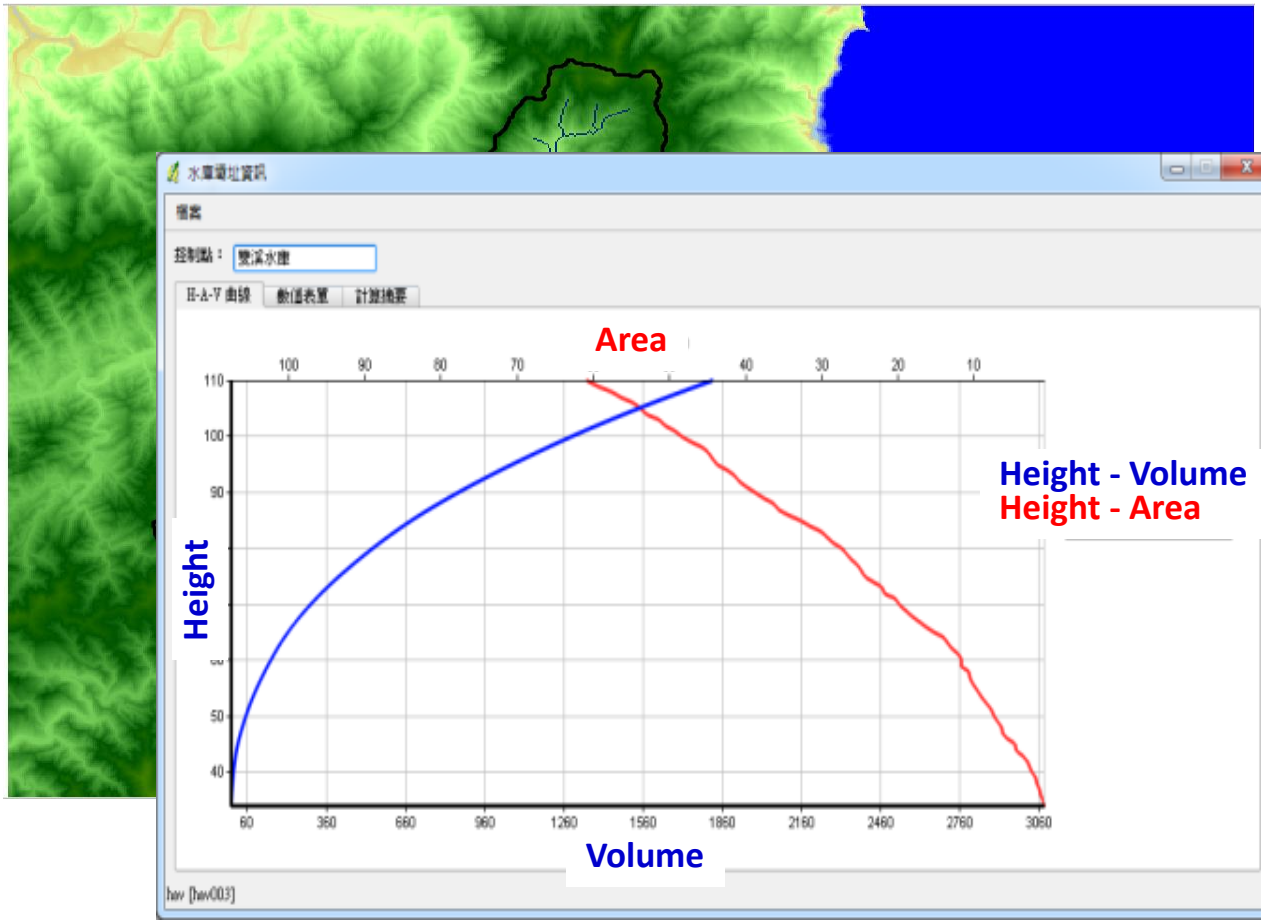**Geologic map and fault distribution**

- Reservoir Storage Anal.
- <u>Geologic Information</u>
- Probable Max. Flood
- Daily Flow Simulation
- Water Supply Anal.
- Transbasin Diversion
- Hillslope Analysis
- Reservoir Life Anal.
- Weather Working Days
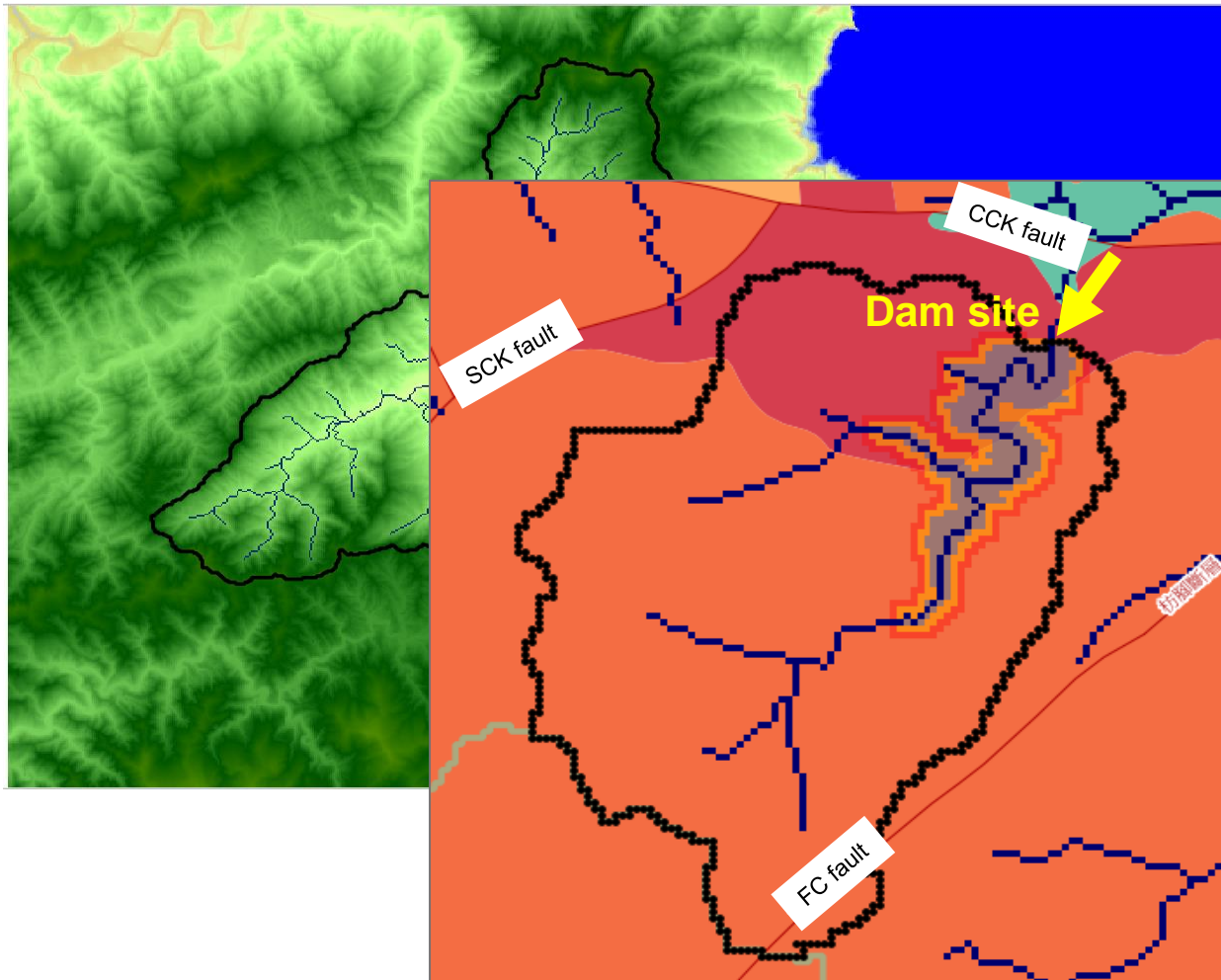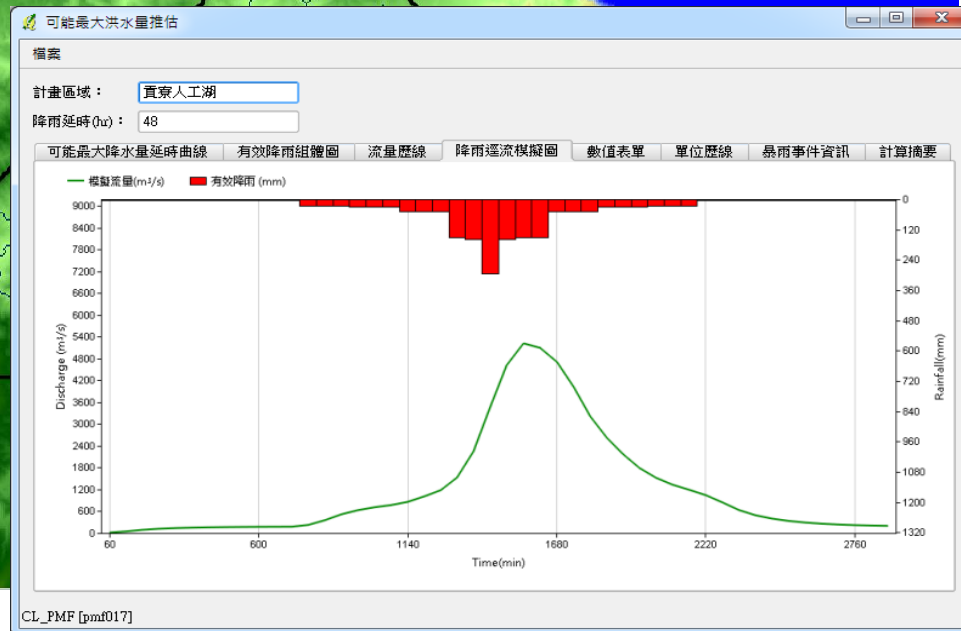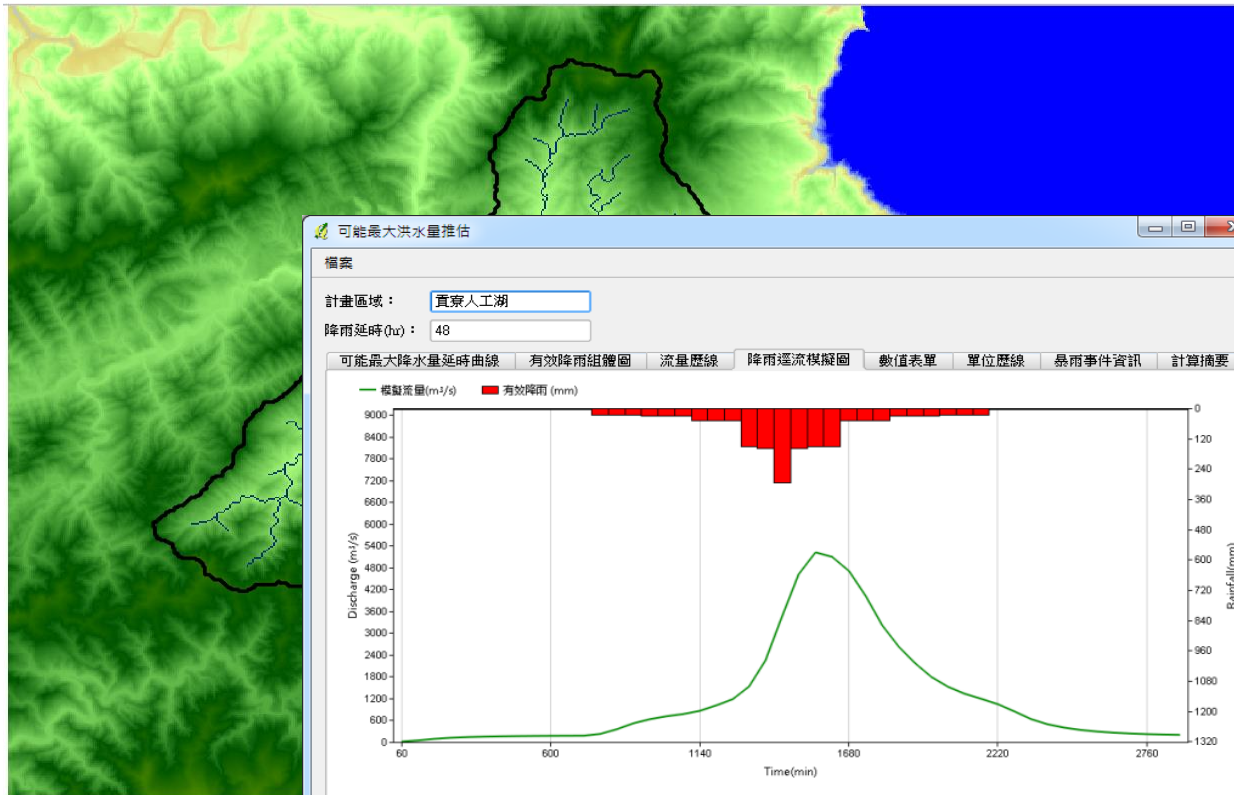
CCK fault

SCK fault

Dam site

FC fault

Platform for water resource development

Reservoir Storage Anal.

Geologic Information

Probable Max. Flood

Daily Flow Simulation

Water Supply Anal.

Transbasin Diversion

Hillslope Analysis

Reservoir Life Anal.

Weather Working Days

Spillway Design

Probable Maximum Precipitation ➡ Probable Maximum Flood (PMF)

Storm transposition & dew-point adjustment

Platform for water resource development

Daily-flow simulation at gauged or ungauged site

Reservoir Storage Anal.

Geologic Information

Probable Max. Flood

Daily Flow Simulation

Water Supply Anal.

Transbasin Diversion

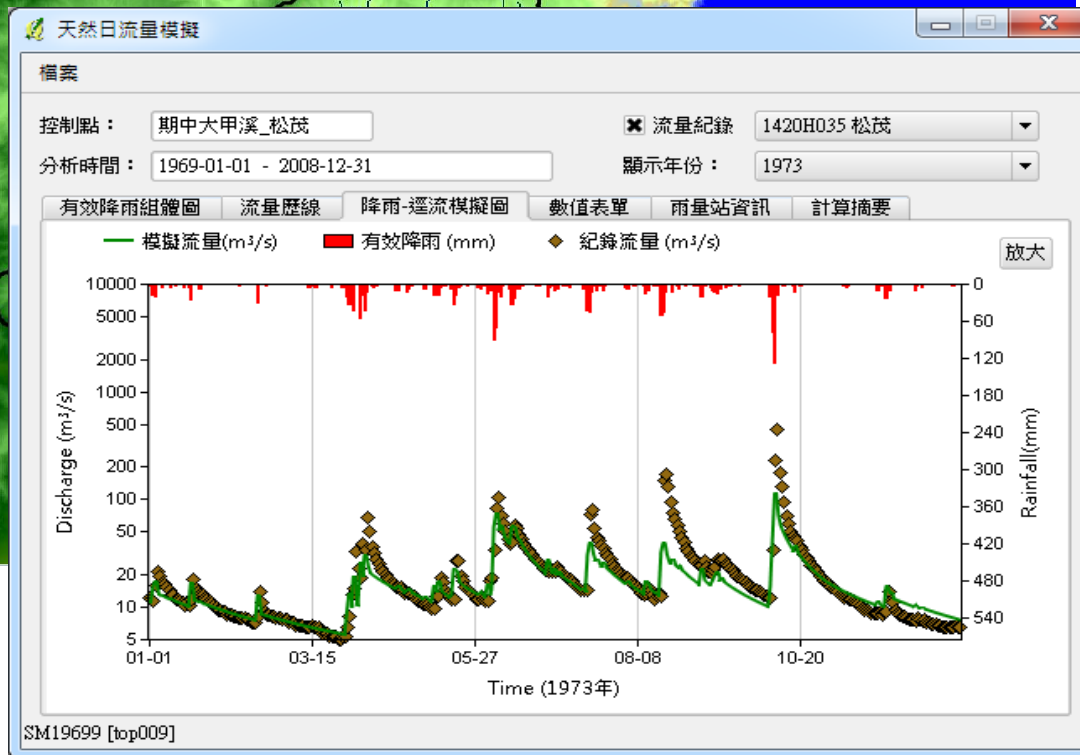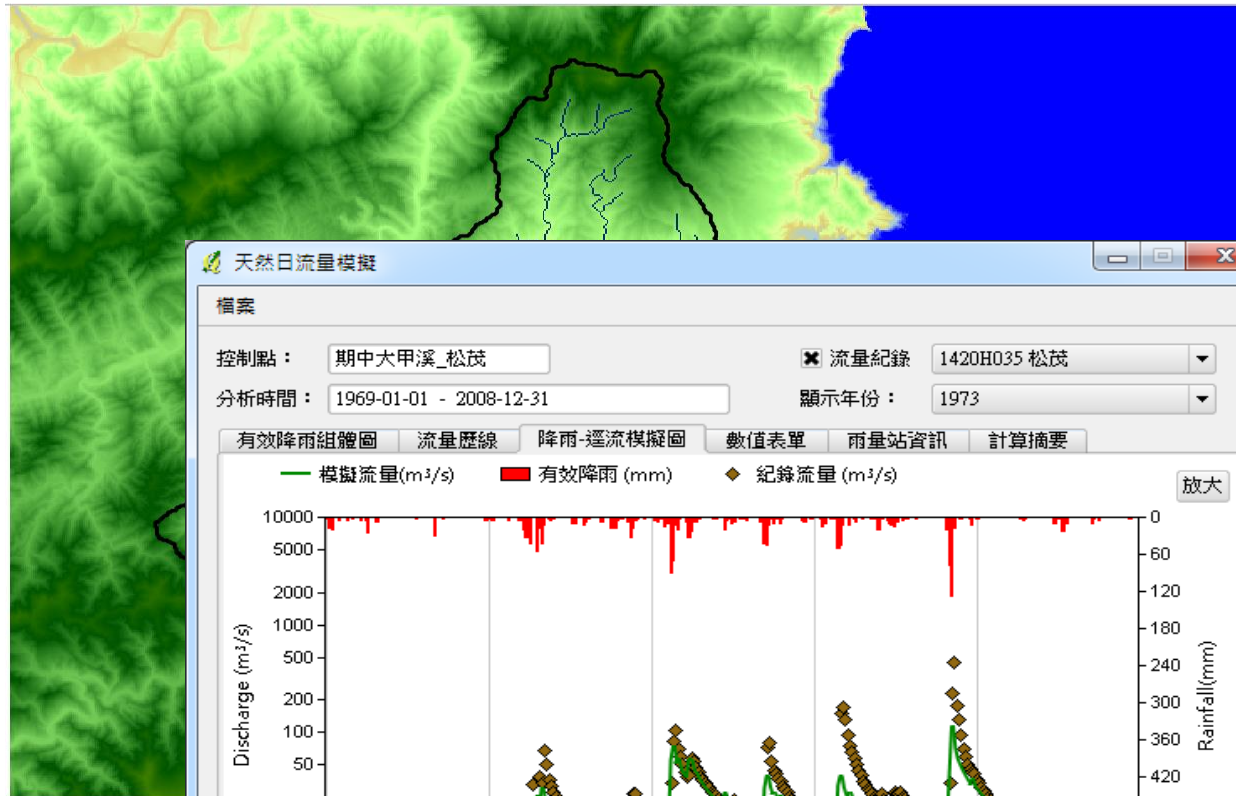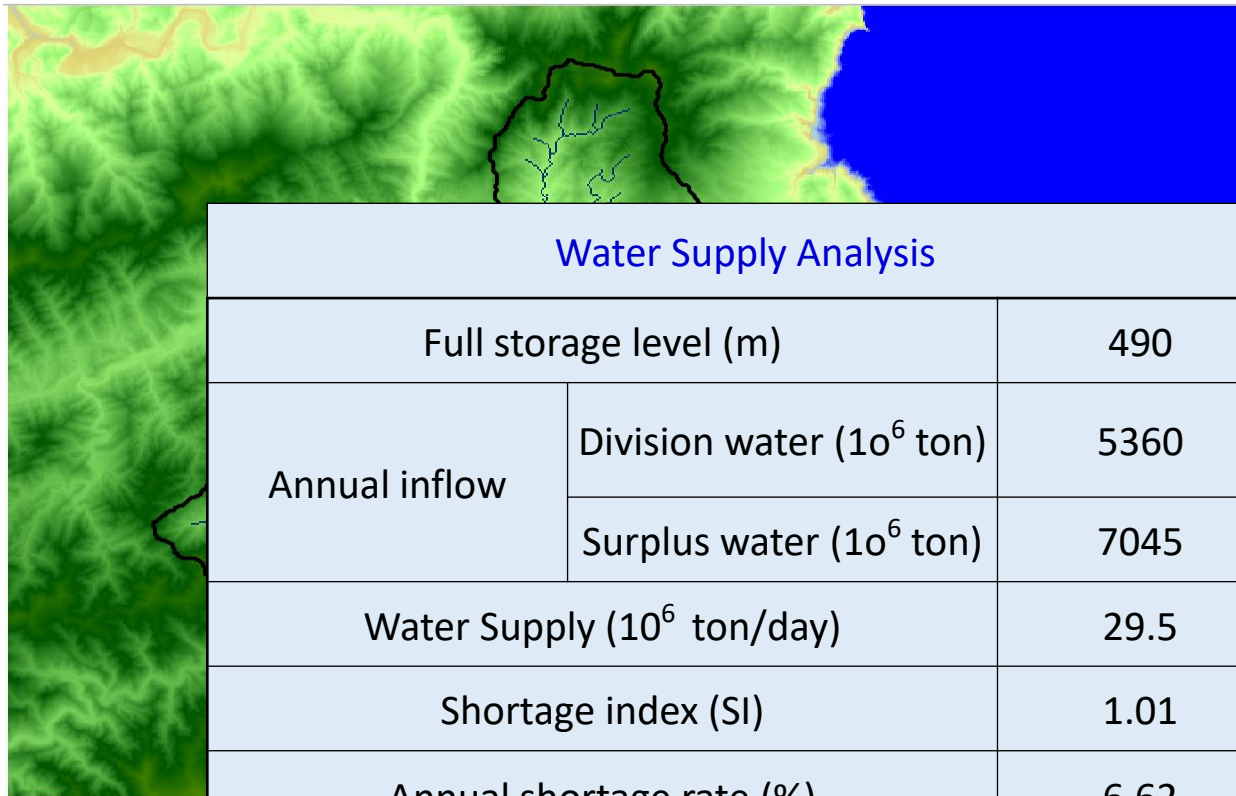Hillslope Analysis

Reservoir Life Anal.

Weather Working Days

Platform for water resource development

Water Supply Analysis		
Full storage level (m)		490
Annual inflow	Division water (10^6 ton)	5360
	Surplus water (10^6 ton)	7045
Water Supply (10^6 ton/day)		29.5
Shortage index (SI)		1.01
Annual shortage rate (%)		6.62

$$\text{Shortage index} = \frac{100}{N} \times \sum_{n=1}^{N} (\text{annual shortage rate } (\%) \div 100)^2$$

Reservoir Storage Anal.

Geologic Information

Probable Max. Flood

Daily Flow Simulation

Water Supply Anal.

Transbasin Diversion

Hillslope Analysis

Reservoir Life Anal.

Weather Working Days

Water shortage information for a specified dam height

Platform for water resource development

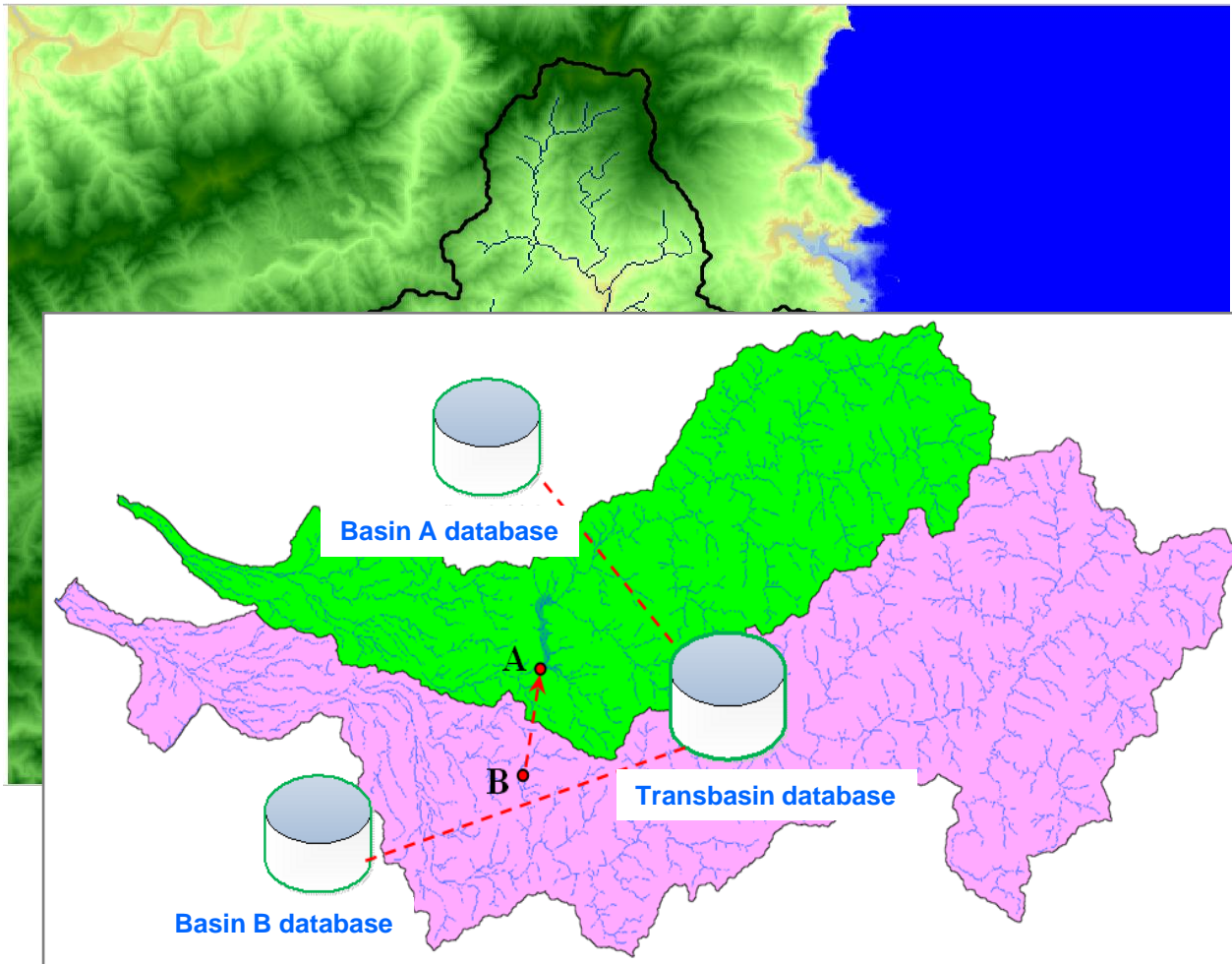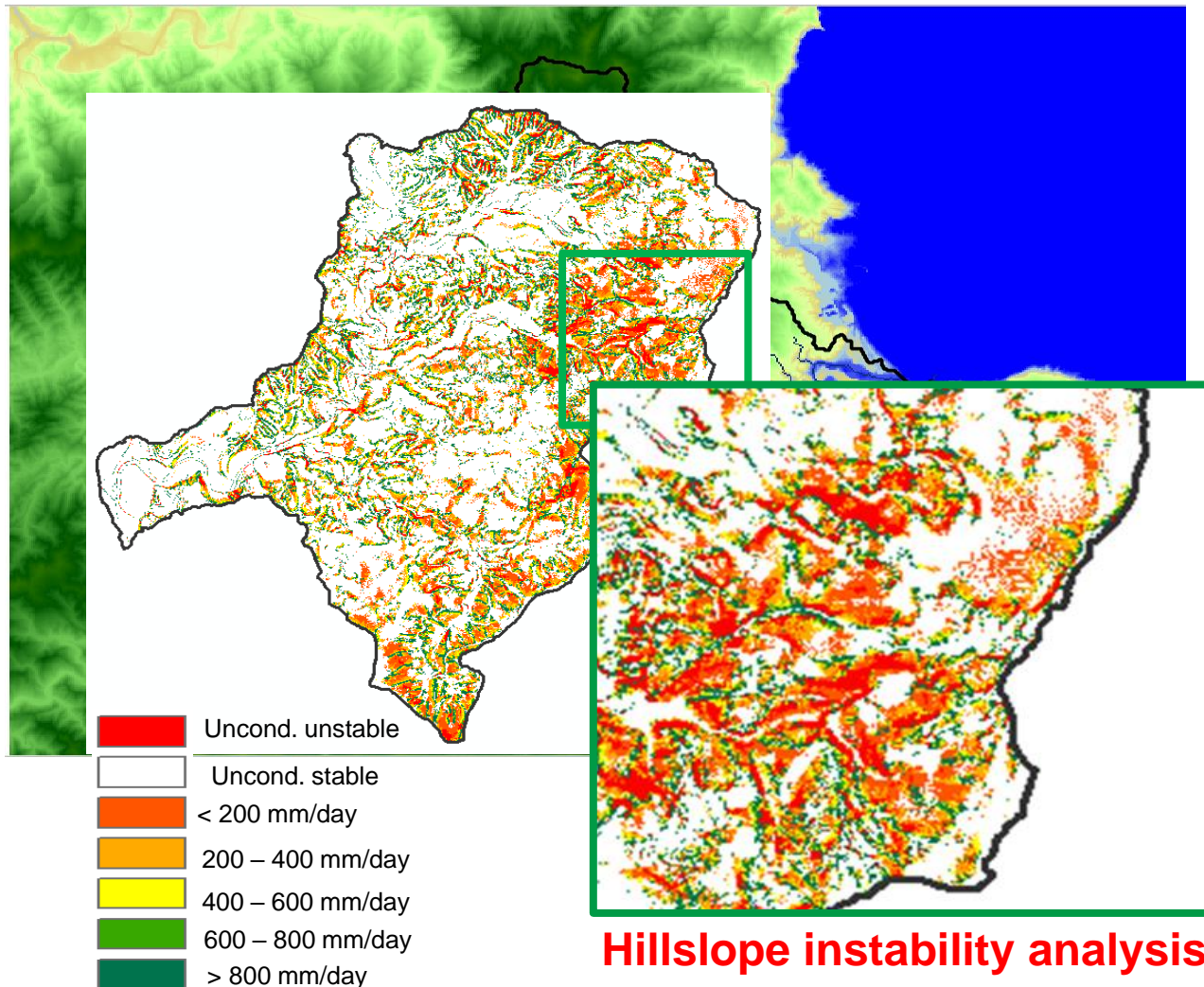**Transbasin diversion database system**

Reservoir Storage Anal.

Geologic Information

Probable Max. Flood

Daily Flow Simulation

Water Supply Anal.

Transbasin Diversion

Hillslope Analysis

Reservoir Life Anal.

Weather Working Days
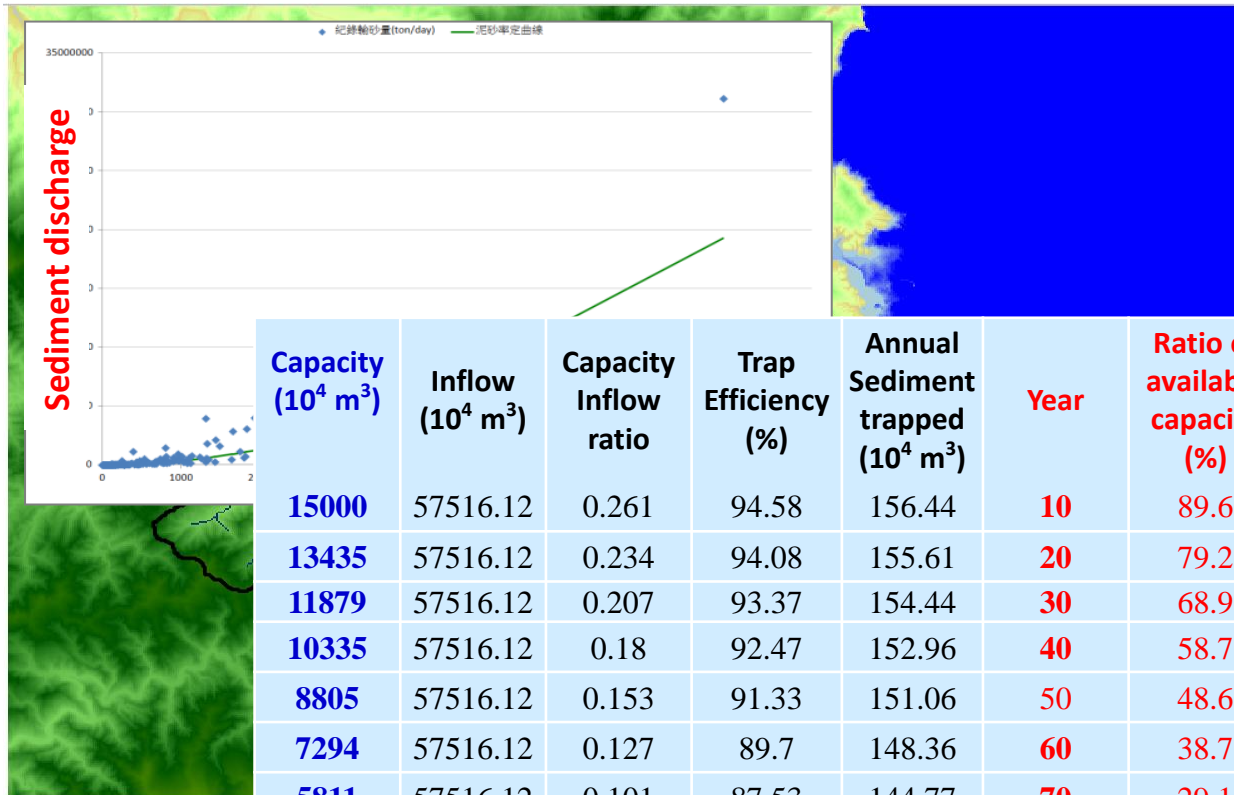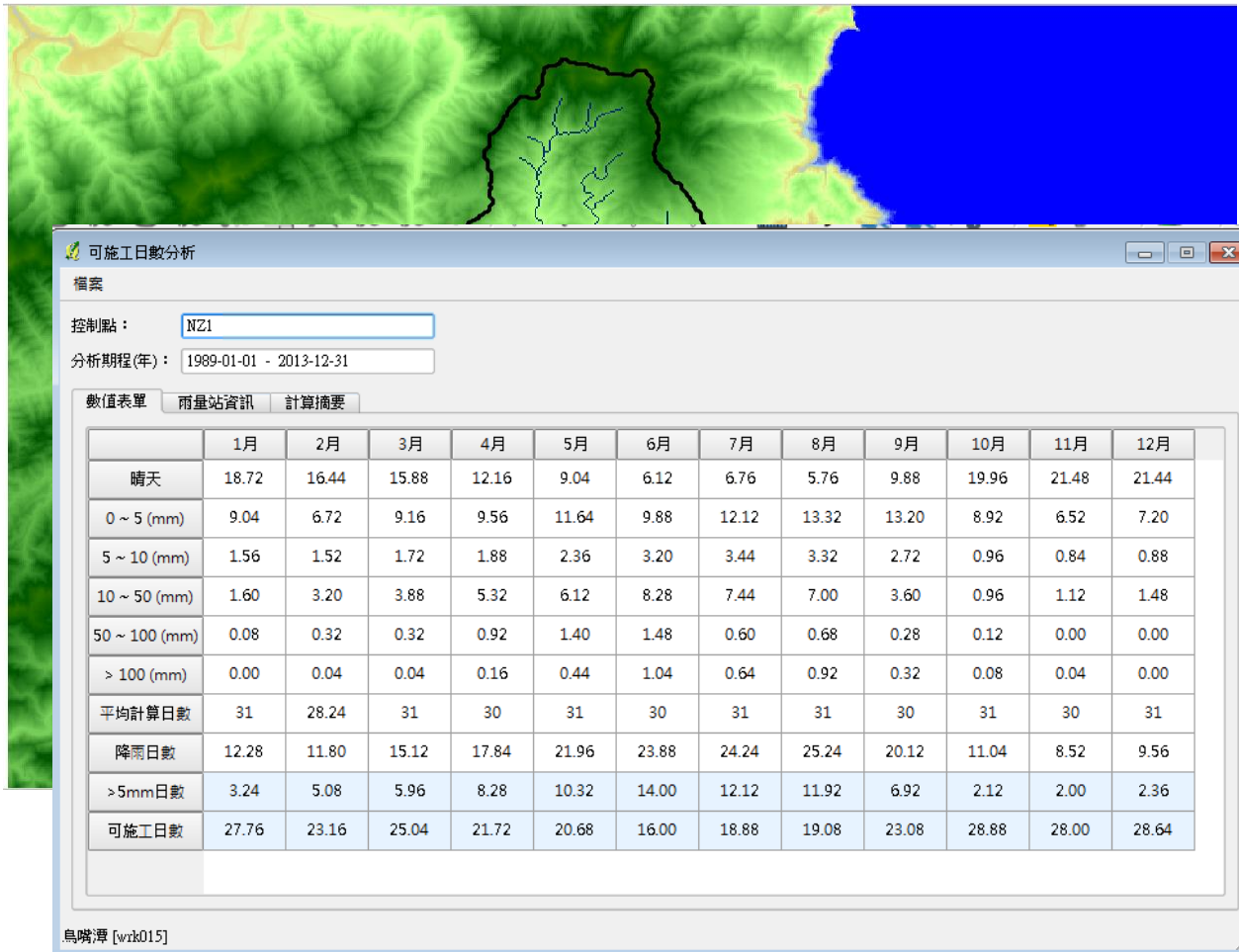
Platform for water resource development

Reservoir Storage Anal.

Geologic Information

Probable Max. Flood

Daily Flow Simulation

Water Supply Anal.

Transbasin Diversion

Hillslope Analysis

Reservoir Life Anal.

Weather Working Days

🟥	Uncond. unstable
⬜	Uncond. stable
🟧	< 200 mm/day
🟧	200 – 400 mm/day
🟨	400 – 600 mm/day
🟩	600 – 800 mm/day
🟩	> 800 mm/day

Hillslope instability analysis

Platform for water resource development

Capacity (10^4 m³)	Inflow (10^4 m³)	Capacity Inflow ratio	Trap Efficiency (%)	Annual Sediment trapped (10^4 m³)	Year	Ratio of available capacity (%)
15000	57516.12	0.261	94.58	156.44	10	89.6
13435	57516.12	0.234	94.08	155.61	20	79.2
11879	57516.12	0.207	93.37	154.44	30	68.9
10335	57516.12	0.18	92.47	152.96	40	58.7
8805	57516.12	0.153	91.33	151.06	50	48.6
7294	57516.12	0.127	89.7	148.36	60	38.7
5811	57516.12	0.101	87.53	144.77	70	29.1
4363	57516.12	0.076	83.99	138.93	80	19.8
2974	57516.12	0.052	77.87	128.8	90	11.2
1686	57516.12	0.029	67.16	111.08	100	3.8

Reservoir sedimentation analysis
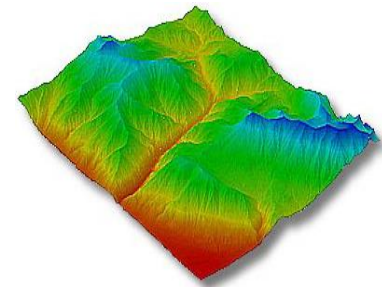
Reservoir Storage Anal.

Geologic Information

Probable Max. Flood

Daily Flow Simulation

Water Supply Anal.

Transbasin Diversion

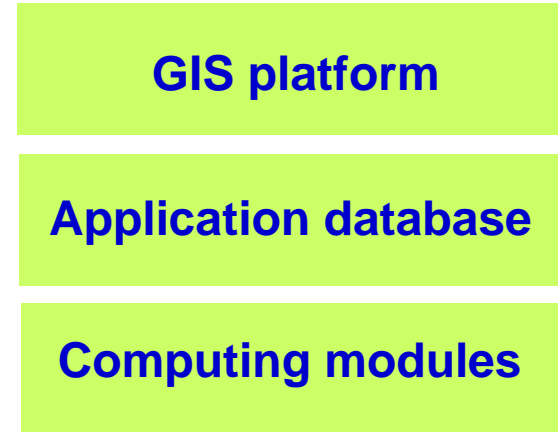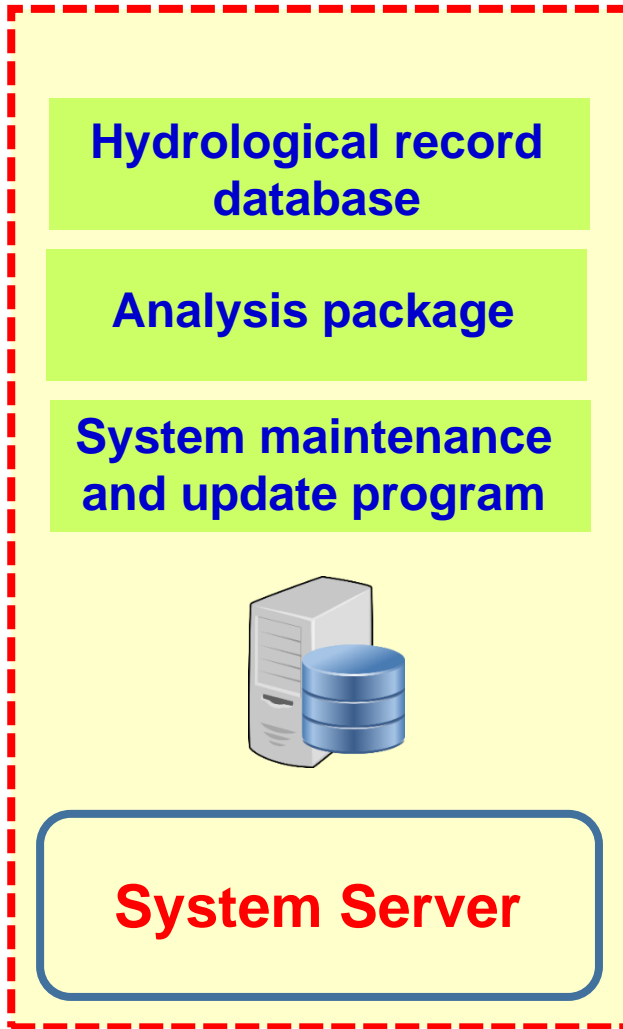Hillslope Analysis

Reservoir Life Anal.

Weather Working Days

Platform for water resource development

Reservoir Storage Anal.

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Daily Flow Simulation

Water Supply Anal.

Transbasin Diversion

Hillslope Analysis

Reservoir Life Anal.

Weather Working Days

可施工日數分析

檔案

控制點： NZ1

分析期程(年)： 1989-01-01 - 2013-12-31

數值表單 | 雨量站資訊 | 計算摘要

	1月	2月	3月	4月	5月	6月	7月	8月	9月	10月	11月	12月
晴天	18.72	16.44	15.88	12.16	9.04	6.12	6.76	5.76	9.88	19.96	21.48	21.44
0 ~ 5 (mm)	9.04	6.72	9.16	9.56	11.64	9.88	12.12	13.32	13.20	8.92	6.52	7.20
5 ~ 10 (mm)	1.56	1.52	1.72	1.88	2.36	3.20	3.44	3.32	2.72	0.96	0.84	0.88
10 ~ 50 (mm)	1.60	3.20	3.88	5.32	6.12	8.28	7.44	7.00	3.60	0.96	1.12	1.48
50 ~ 100 (mm)	0.08	0.32	0.32	0.92	1.40	1.48	0.60	0.68	0.28	0.12	0.00	0.00
> 100 (mm)	0.00	0.04	0.04	0.16	0.44	1.04	0.64	0.92	0.32	0.08	0.04	0.00
平均計算日數	31	28.24	31	30	31	30	31	31	30	31	30	31
降雨日數	12.28	11.80	15.12	17.84	21.96	23.88	24.24	25.24	20.12	11.04	8.52	9.56
>5mm日數	3.24	5.08	5.96	8.28	10.32	14.00	12.12	11.92	6.92	2.12	2.00	2.36
可施工日數	27.76	23.16	25.04	21.72	20.68	16.00	18.88	19.08	23.08	28.88	28.00	28.64

鳥嘴潭 [wrk015]

Weather working days analysis

Platform System and Database

System structure

Data Observation Network	System Server	Authorized User's Computer
Rainfall & discharge	**Hydrological record database**	**GIS platform**
Topography	**Analysis package**	**Application database**
Land cover	**System maintenance and update program**	**Computing modules**

Programs, database, and platform

Hydrological analysis programs

Hydrological programs were developed by the GIS Research Group in National Taiwan Ocean Univ., only a freeware HEC-RAS was included in the system.

Database and Platform

Open source software PostgreSQL and Quantum GIS were used to develop the database and platform system. The system can run on all major operating systems, including Linux, UNIX, and Windows.

Computer specifications

User's computer

- Processor : Intel Core 2 Duo
- Memory   : 4GB of RAM
- Hard Disk : 10 GB

System Server

- Processor : 2.4 GHz 4-core
                  64 bit CPU
- Memory : 8 GB of RAM
- Hard Disk : 200 GB
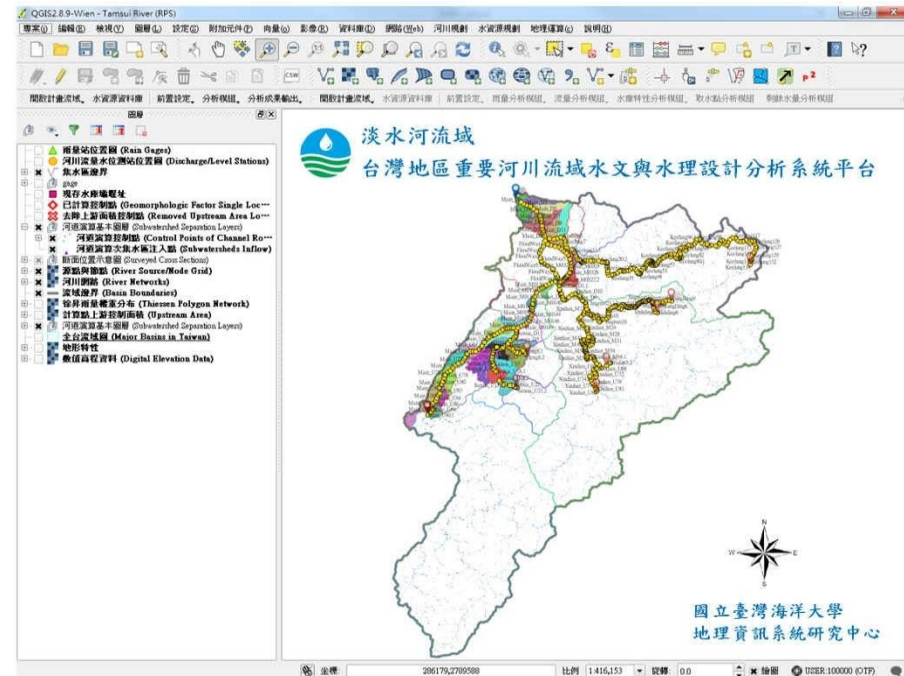
Data required in the platform

Major datasets

- **Digital elevation model dataset (DEM)**
- **Rainfall data (hourly and/or daily data)**
- **Flow data (hourly and/or daily data)**

Auxiliary datasets

- Land cover map
- Road map
- Administrative area map
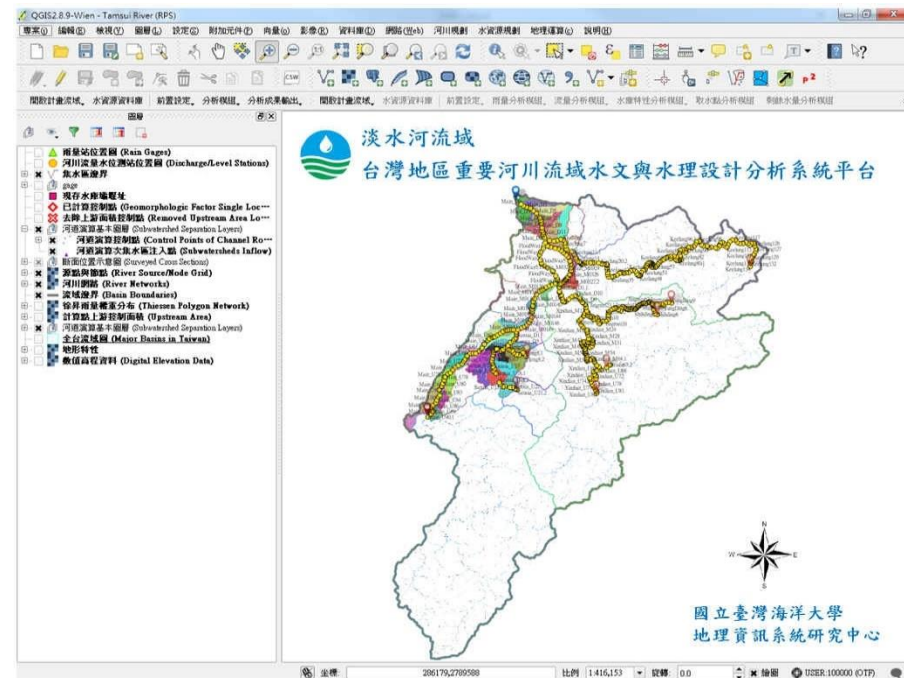
Digital elevation datasets

NASA ASTER GDEM Version 2 (2011)
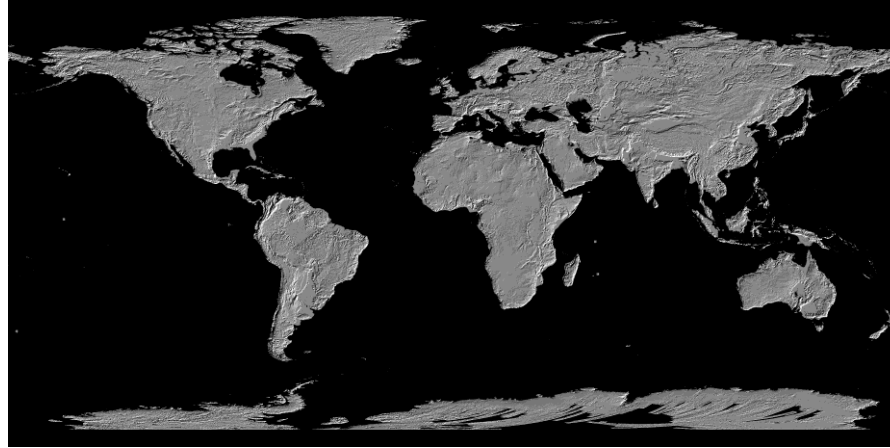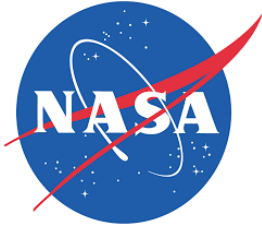
Global
Digital Elevation Model
30m×30m

Taiwan DEM dataset (2007)
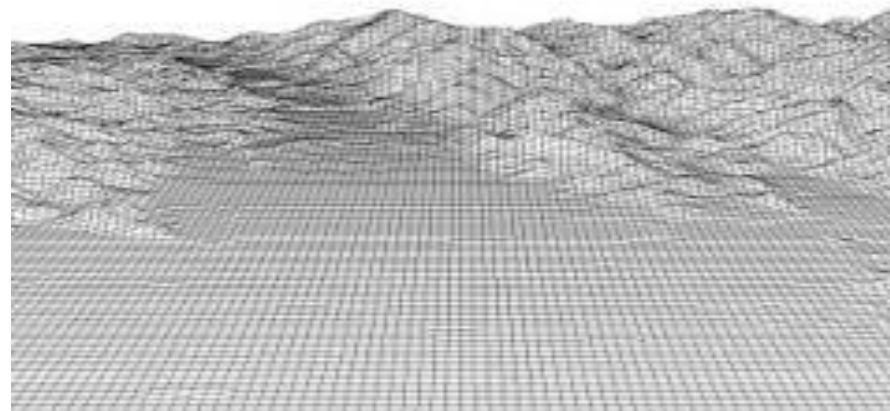
Aerial Photogrammetry
5m X 5m

Rainfall and flow datasets

Rainfall gauging

122 in Thailand, 100 in Philippines

172 in Vietnam, 122 in Cambodia

Flow gauging

River stages can be measured by using

temporal water stage sensors

Only a few hydrological records required for model execution.

Integrated hydrological analysis platform

Flood prevention design

- Watershed Geo.
- Rainfall Freq. Anal.
- Spatial rainfall Anal.
- Watershed Runoff Routing
- Channel Flow Routing
- Storm Event sim.
- Design Discharge
- Flood inundation Sim.
- Urban flood sim.

Water resource development

- Reservoir Storage Anal.
- Geologic Information
- Probable Max. Flood
- Daily Flow Simulation
- Water Supply Analysis
- Transbasin Diversion
- Hillslope Analysis
- Reservoir Life Analysis
- Weather working days

Platform & Database

- Quantum GIS
- PostgreSQL
- Web Service

Summary

The distinctive features of the platform are as follows:

■ **All-in-one basin solution**

   Integrating hydrology, hydraulic, water resource management, and database system.

■ **Efficient operating environment**

   User-friendly GIS platform, few input data required; Results (figures & tables) are supported by Word files.

■ **Information update simultaneously**

   The analysis results can be updated simultaneously with the hydrological record database.

Flood Prevention Design
Water Resource Development
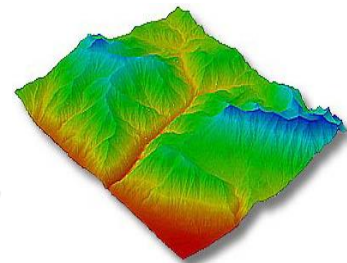
Thank you for your attention

Kwan Tun LEE
Department of River & Harbor Engineering
National Taiwan Ocean University, Taiwan
Email: ktlee@ntou.edu.tw

Digital elevation model (DEM)

Flow direction is determined according to the elevation in the eight adjacent cells

- Flow direction determination

- Depressionless

- Flow accumulation value calculation

- Channel network extraction

- Subwatershed delineation

- Geomorphologic factors determination

30m
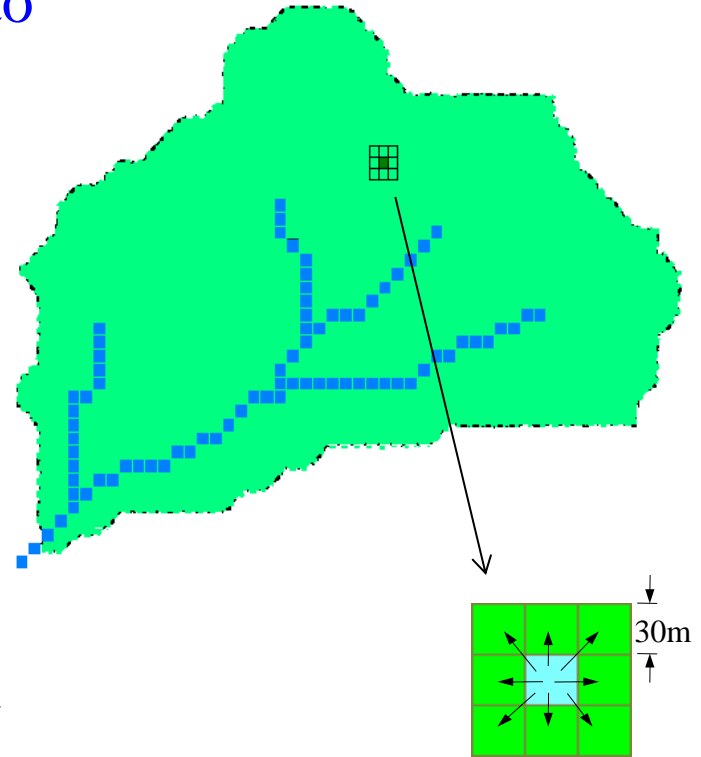
In 2014, NASA released **globally 30m resolution topographic data** generated from the Shuttle Radar Topography Mission (SRTM).

Platform system development

To create a new platform system, the following steps are required:

- ■ DEM processing

- ■ Link between <u>system server</u> and <u>data observation network</u>

- ■ Model parameter calibration and verification

- ■ Training program & System maintenance
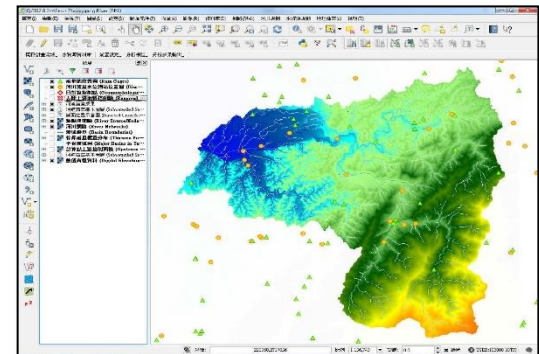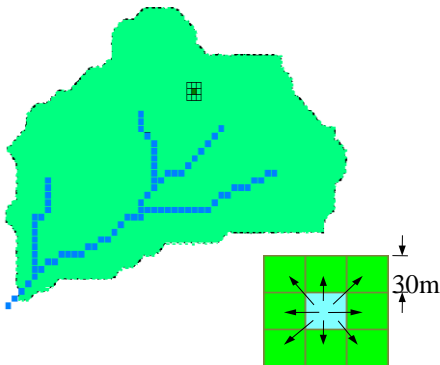
Analysis of water resource development
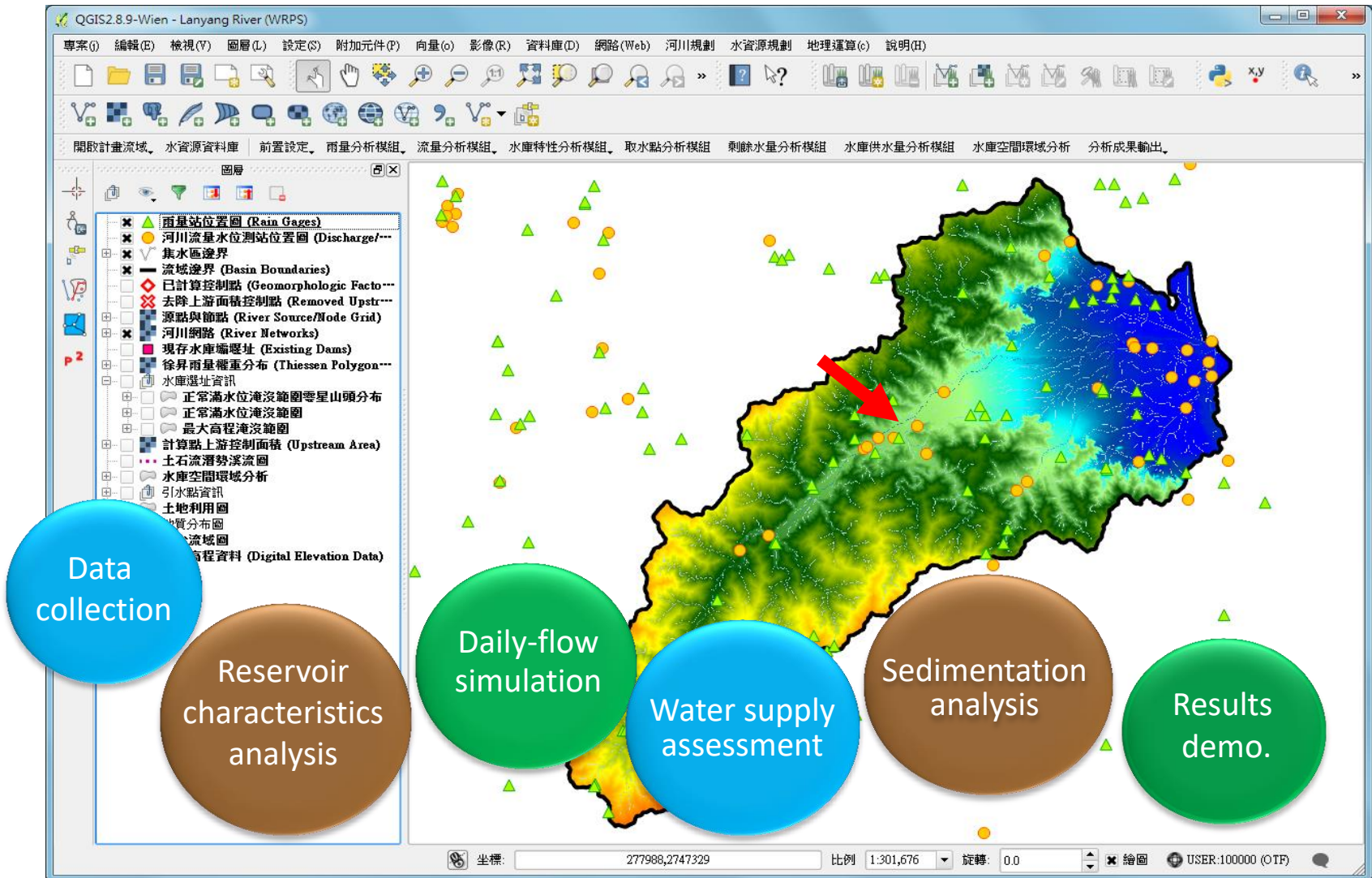
Natural disasters in Taiwan

■ There are on average 3.6 typhoons per year in Taiwan which has been regarded as one of the most vulnerable regions in the world.

■ In the meantime, the island suffers from the uneven distribution of rainfall. Drought frequently occurs in the early spring to result in fallow.

What are the distinctive features of our

Integrated Hydrological Analysis Platform *?*

Freeware

HEC-HMS, HEC-RAS, HEC-DSS, SWMM….

Commercial software

SOBEK, MIKE 21, FLO-2D, WMS, 3Di….

Disaster management

■ The Water Resources Agency of Taiwan has proposed integrated basin management, which attempted to increase the resilience of cities during severe rainstorms through <u>flood control structures</u> and <u>land-use management</u>.

■ Under the premise of environmental protection, the authority also tried <u>to find new reservoir sites</u> to resolve the water shortage problem.

Platform structure

User

Digital elevation data

Spatial Data

Integrated hydrological Platform
Quantum GIS

User interface

User interface

Supplement database

Web service

Records database

Server

Results database

PostgreSQL

Geomorphologic model

Hydrologic model

Hydraulic model

Fortran
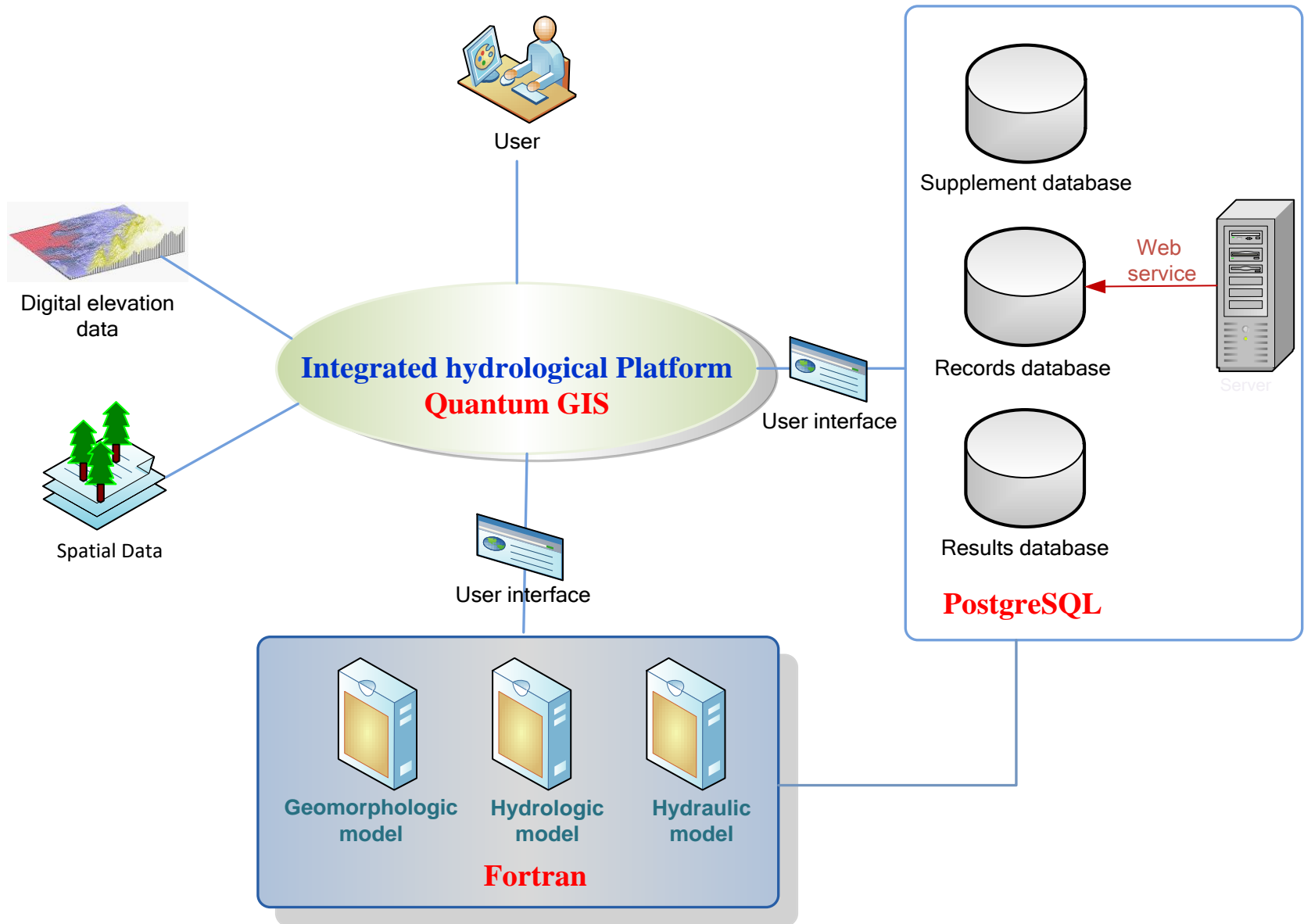
Summary

- Hydrological sciences are multidisciplinary in nature. The GIS platform can provide a convenient way to integrate data, models, and knowledge in hydrological sciences.

- The integrated platforms has been developed for flood prevention design and water resource development, which require only few hydrological records for model parameters calibration.

- The analysis results can be updated at any time automatically if the platform is linked with hydrological record datasets.

Feasibility analysis of possible dam sites
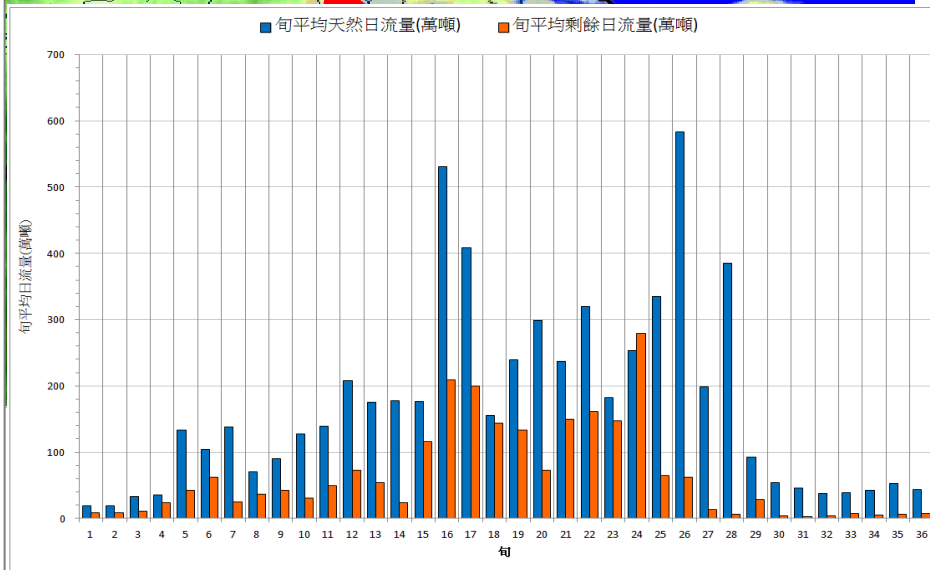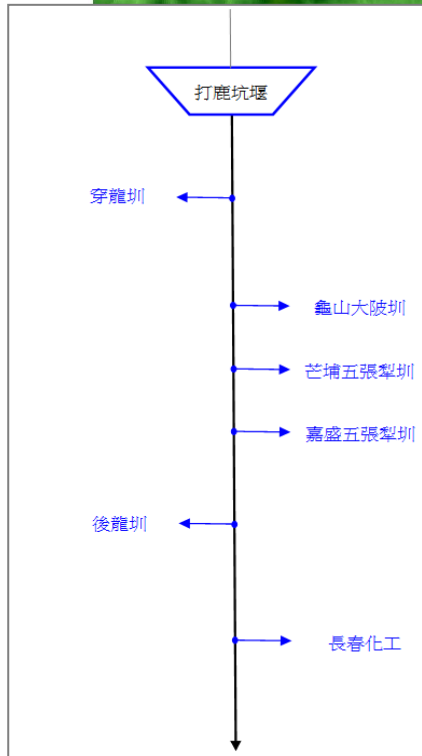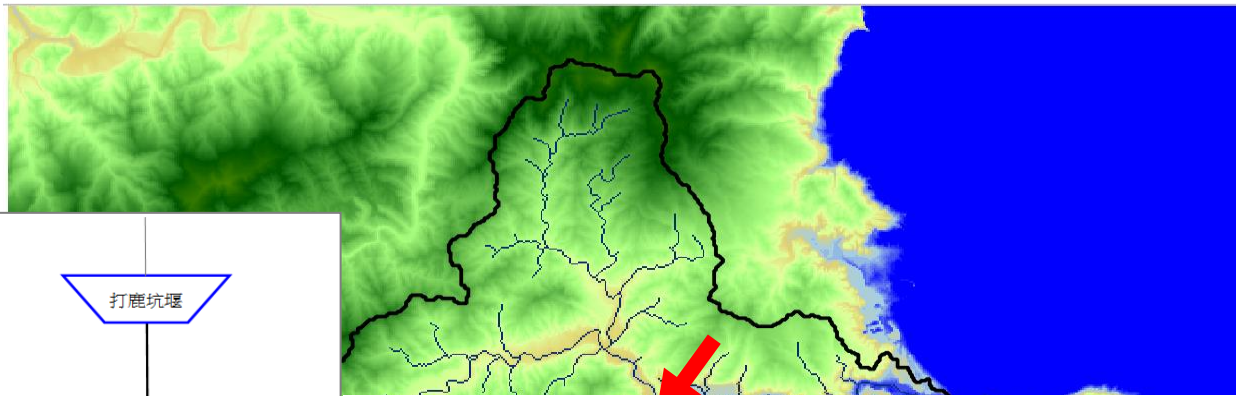
Reservoir storage anal.

Geologic information

Probable max. flood

Daily flow simulation

Flow exceedance anal.

Surplus water anal.

Water supply anal.

Transbasin diversion

Landslide anal.

Reservoir life expectancy

Weather working days

Flow diversion   **Flow exceedance analysis of surplus water**
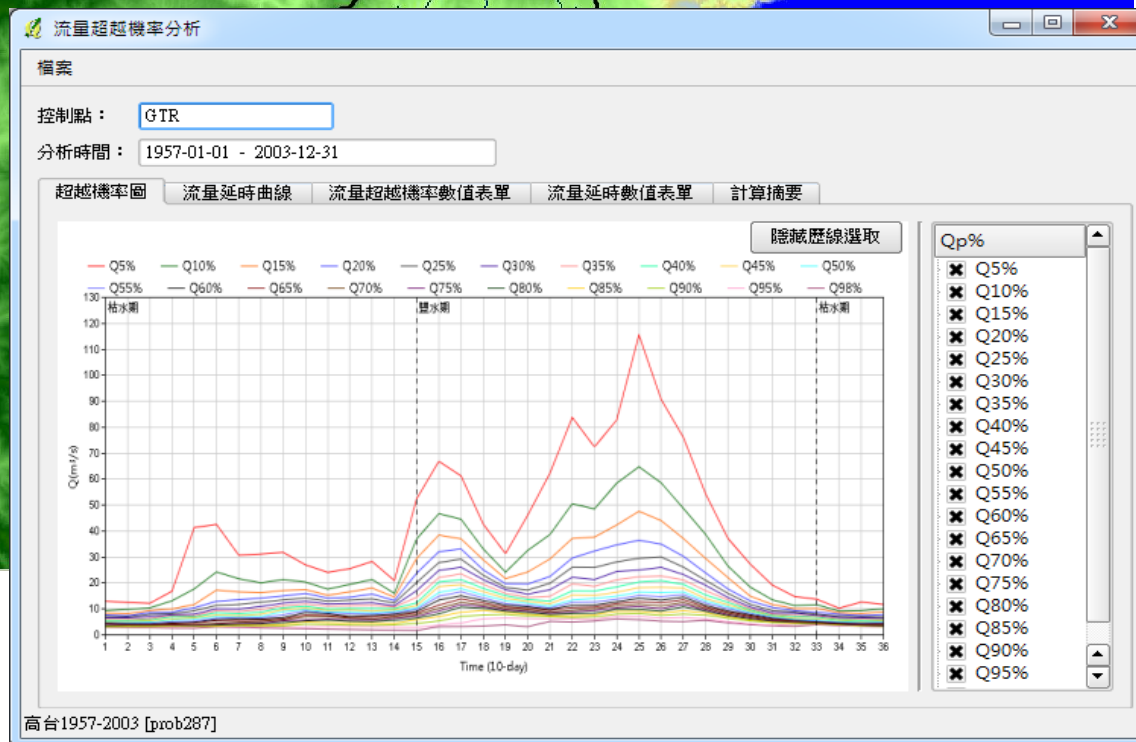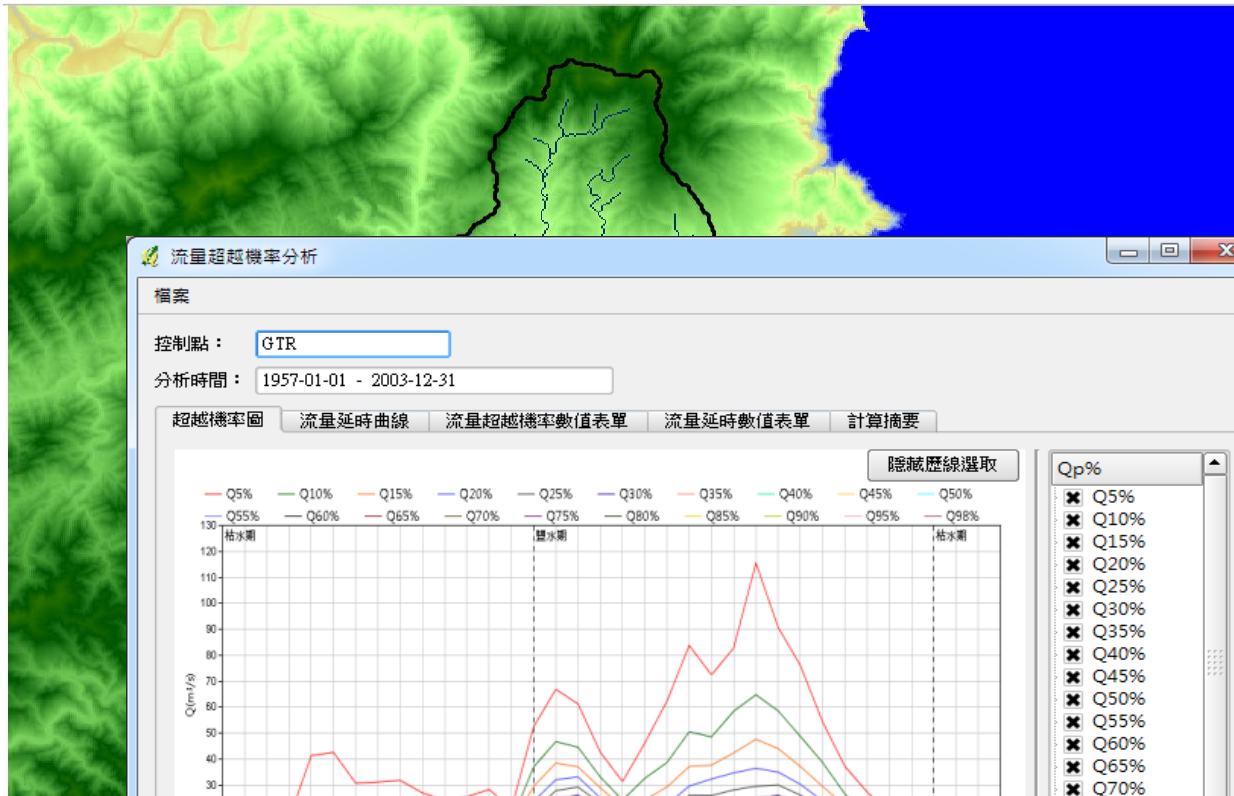
Feasibility analysis of possible dam sites

Temporal probability of the daily-flow series

Reservoir storage anal.

Geologic information

Probable max. flood

Daily flow simulation

Flow exceedance anal.

Surplus water anal.

Water supply anal.

Transbasin diversion

Landslide anal.

Reservoir life expectancy

Weather working days

Water Resource Agency, Ministry of Economic Affairs, Taiwan
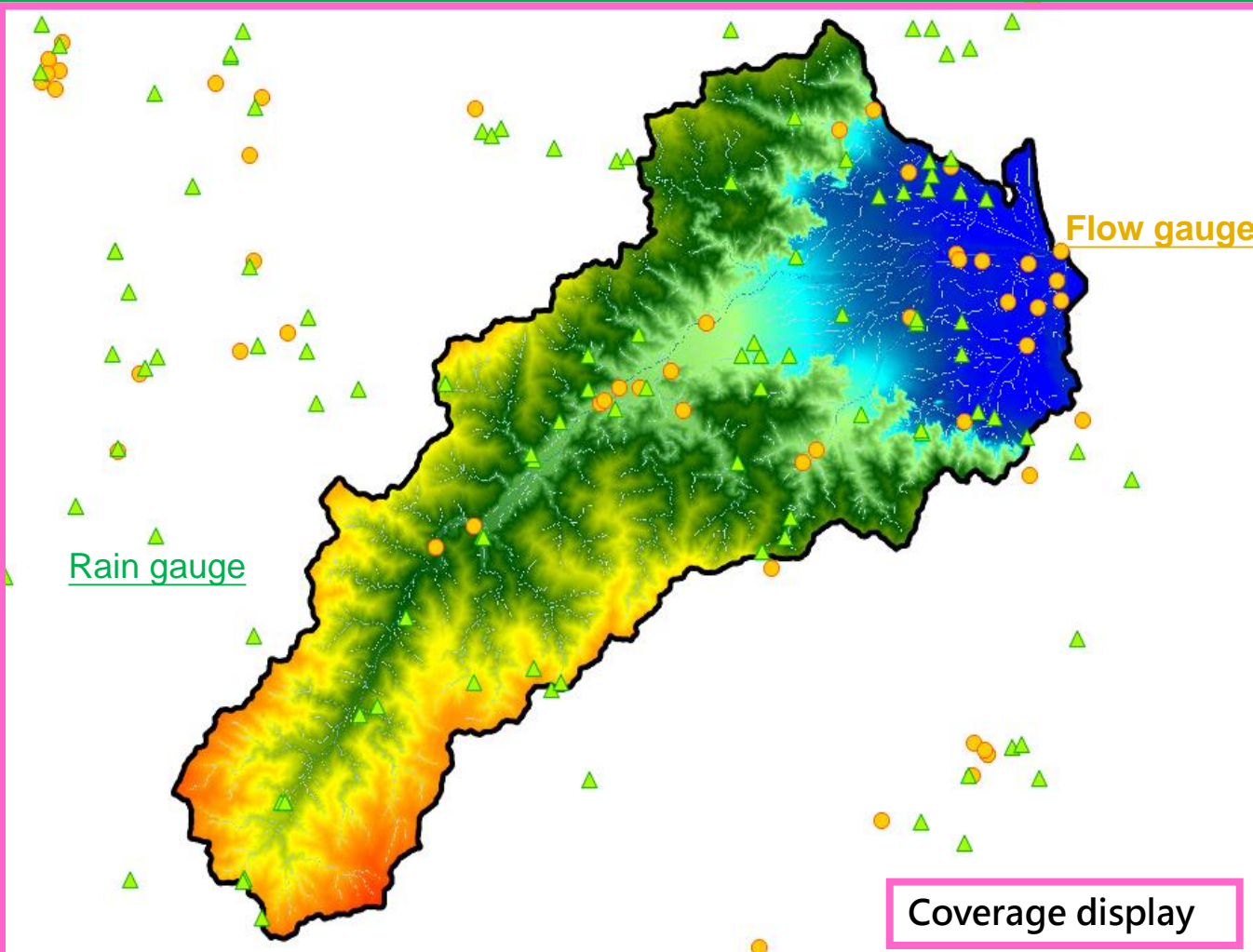
Rainfall data

Rain gauge

Hourly rainfall dataset

Daily rainfall dataset
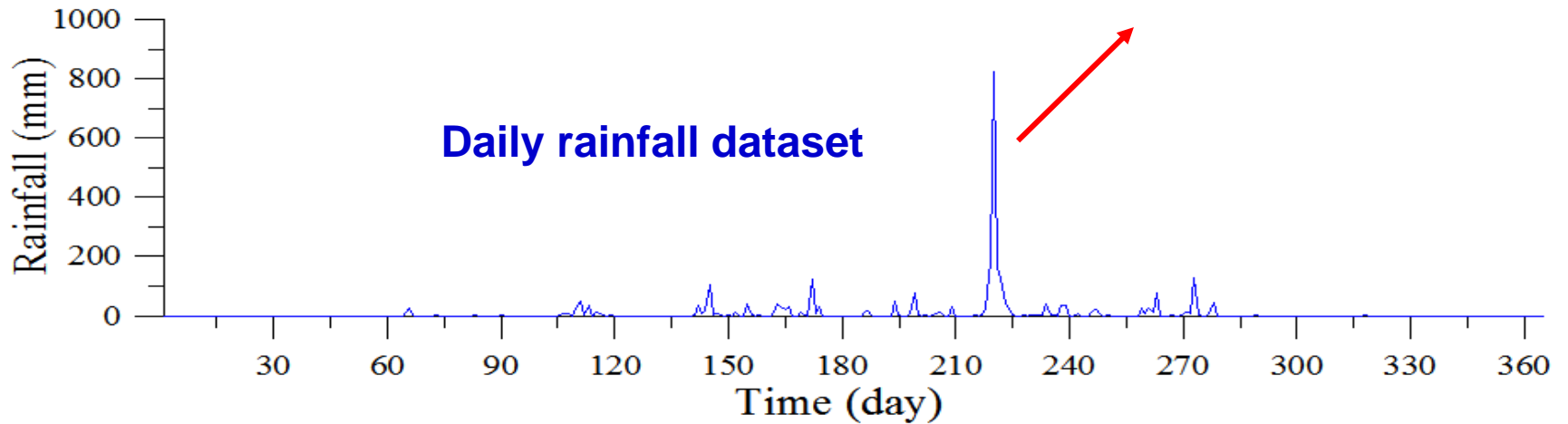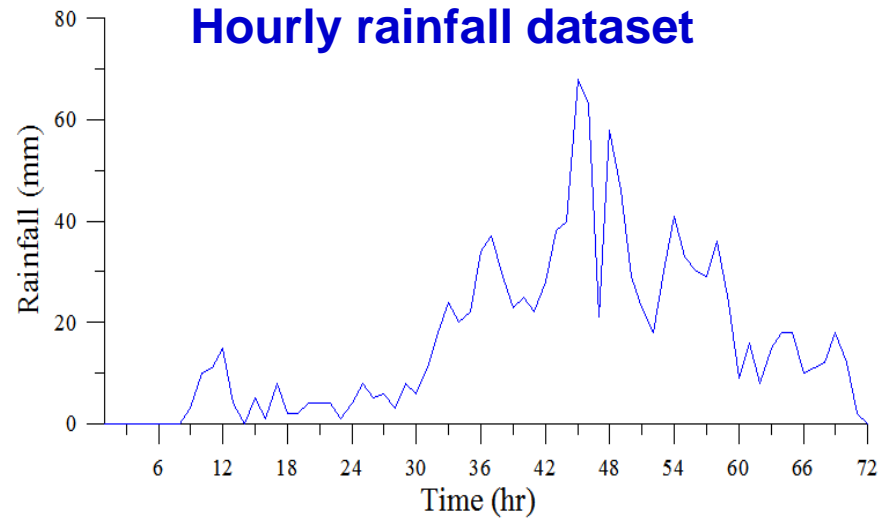
Flow data

Water stage gauge

Hourly flow dataset

Daily flow dataset
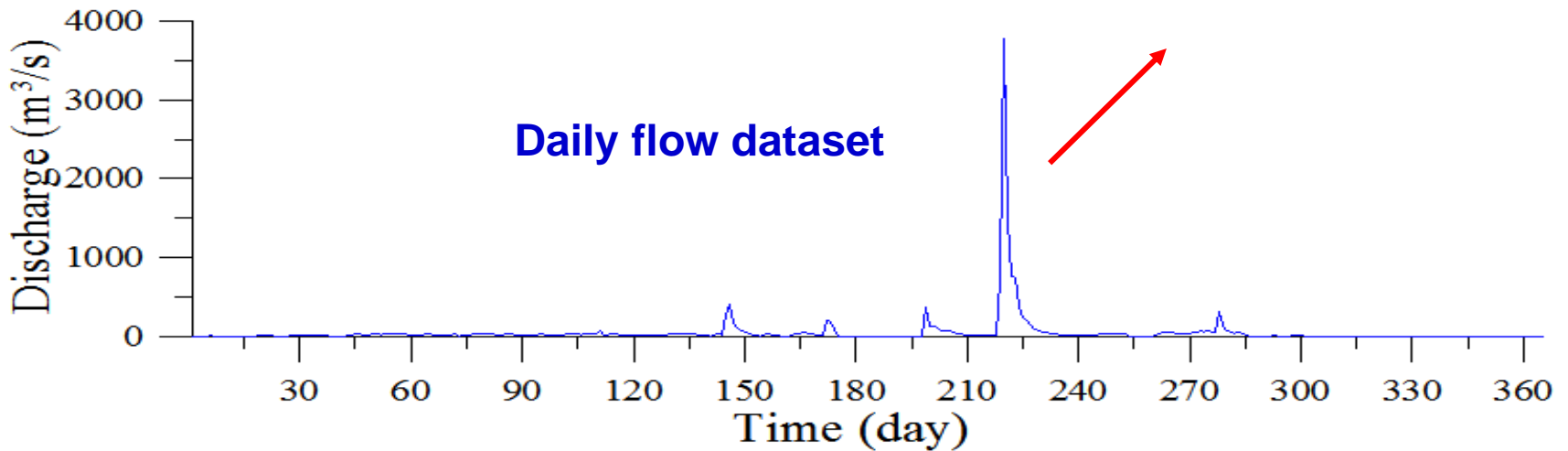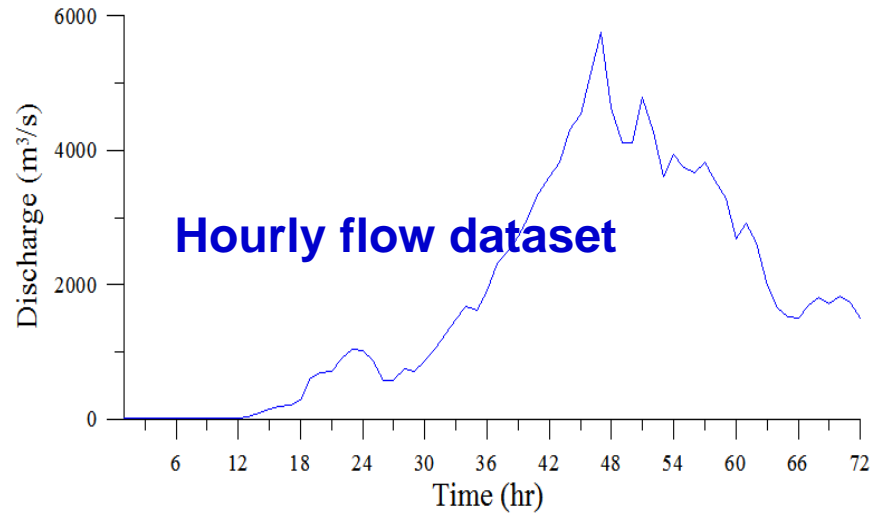
Data, Information, Knowledge, Wisdom
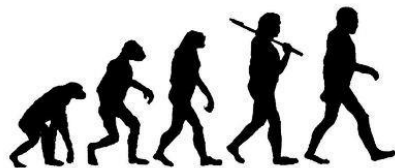
Intuitive platform for engineers

Subwatershed runoff routing

Channel flow routing

RS = 64
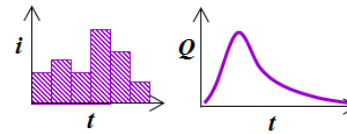
Lateral inflow routing

Data collection & Databank establish

Subwatershed & lateral inflow regions delineating

Spatial rainfall analysis

Subwatershed runoff & lateral inflow routing

Channel flow routing

Results demonstration

Urban flood early warning system

- **Login**
  http://cityflood.cpami.gov.tw

- **Warning areas**

  22 Counties

  322 Townships

- **Rain gauges**

  877 stations

  (real-time 10-min data)

- **Current warning**

- **Early warning**

- **Report production**
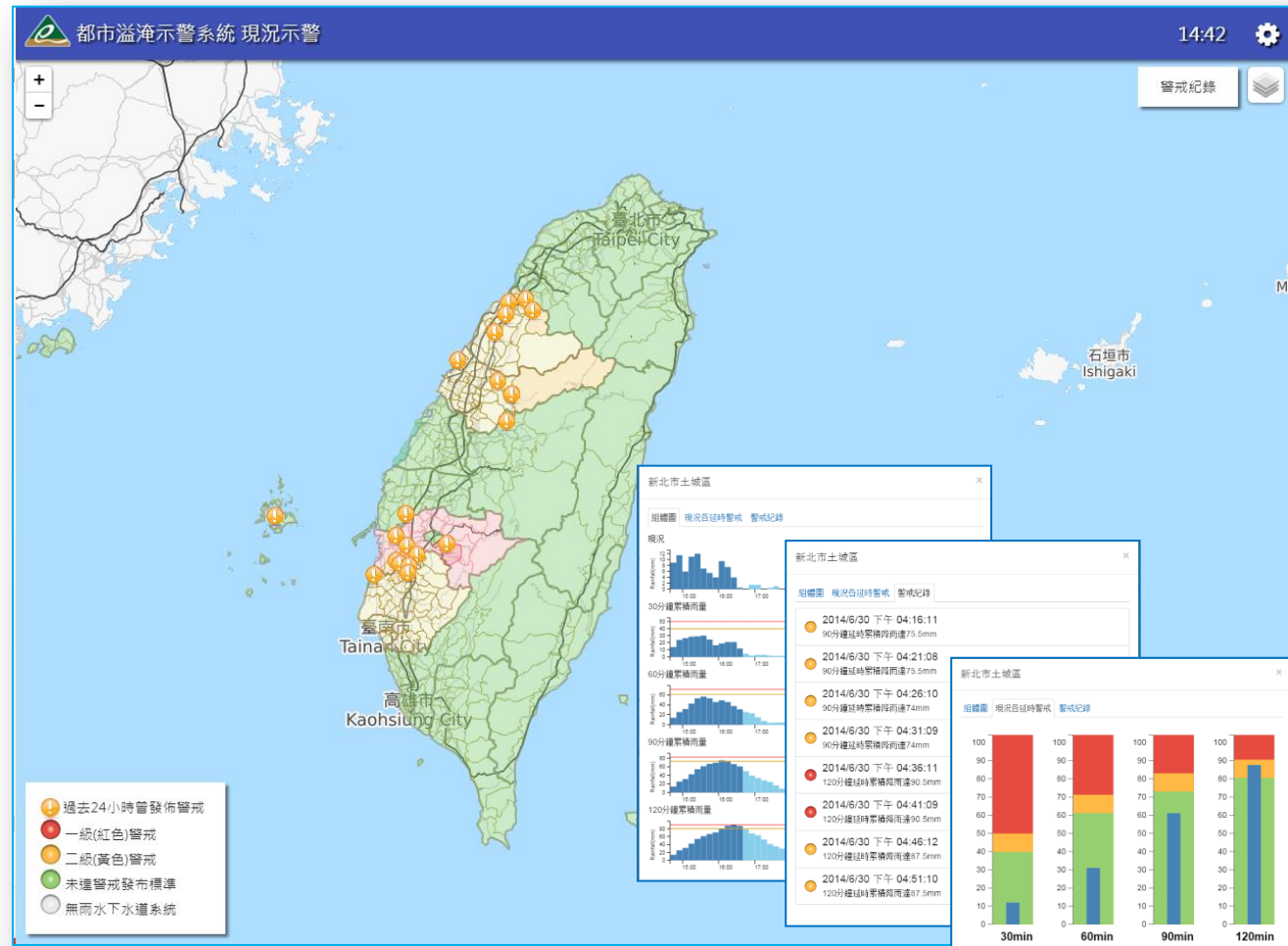
Construction and Planning Agency, Ministry of the Interior, Taiwan

Integrated hydrological platform

upstream subwatershed

tributary subwatershed

lateral inflow region

channel
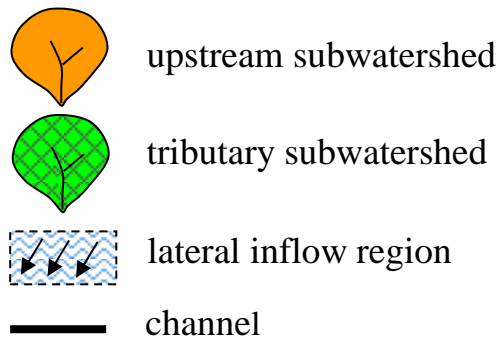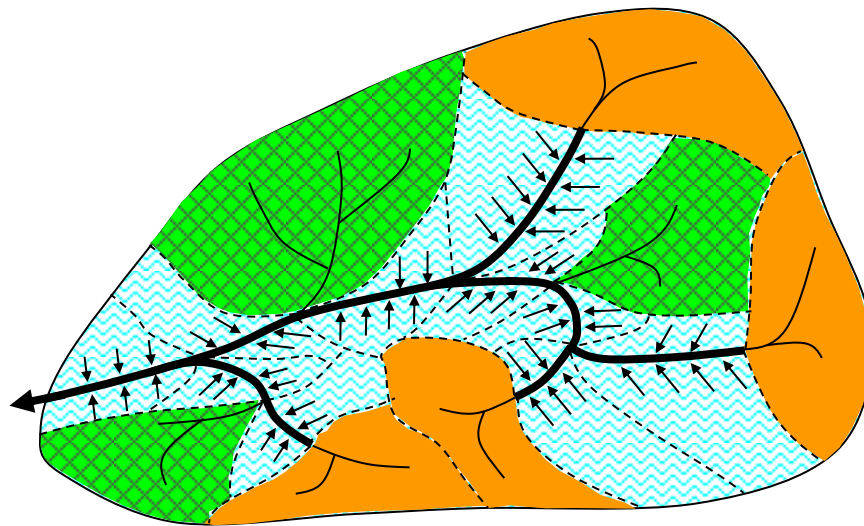
Geomorphologic analysis

- watershed boundary
- stream network
- geomorphologic factors

Hydrological analysis

- rainfall frequency anal.
- rainfall IDF anal.
- runoff simulation

High-flow analysis

- design discharge routing
- flood event routing

Low-flow analysis

- dominate discharge anal.
- stable channel design

Integrated platform

- open source databank
- open source platform

Sewer flow monitoring
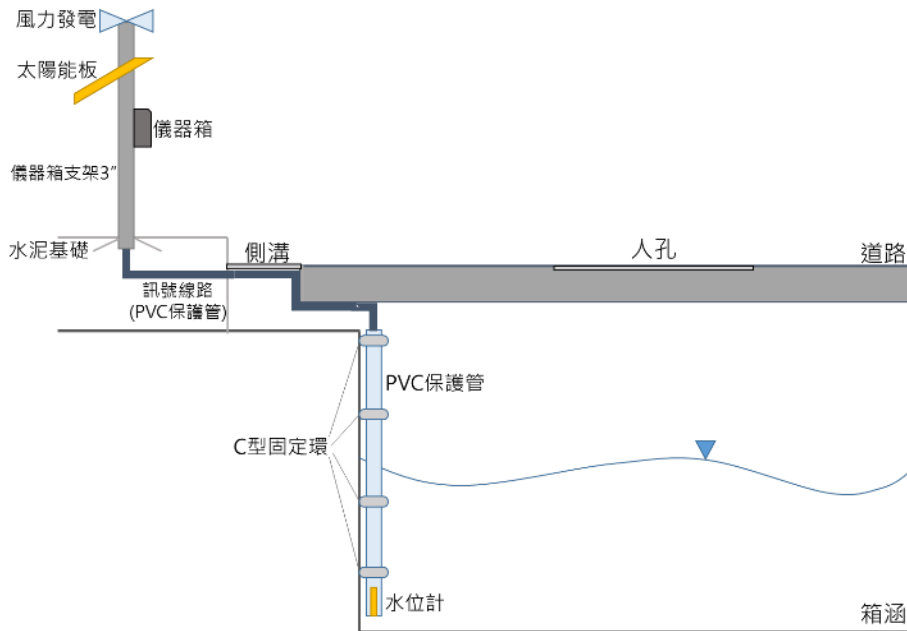
Real-time stage recording system

- 布置費用高昂
- 建置時間冗長
- 需足夠空間與電力通訊傳輸
- 定期執行軟/硬體設施維護管理

Automatic recording system

- 費用低廉
- 建置時間快速
- 裝備移置方便
- 設施易於維護管理
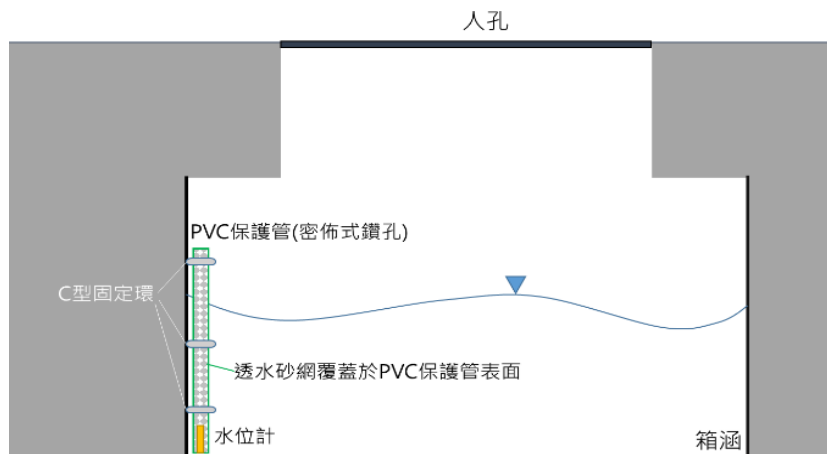
Watershed runoff analysis

- **Upstream watershed** → Watershed rainfall-runoff model
- **Midstream sewer system** → Sewer-street runoff model
- **Downstream drainage system** → Channel-flow routing model
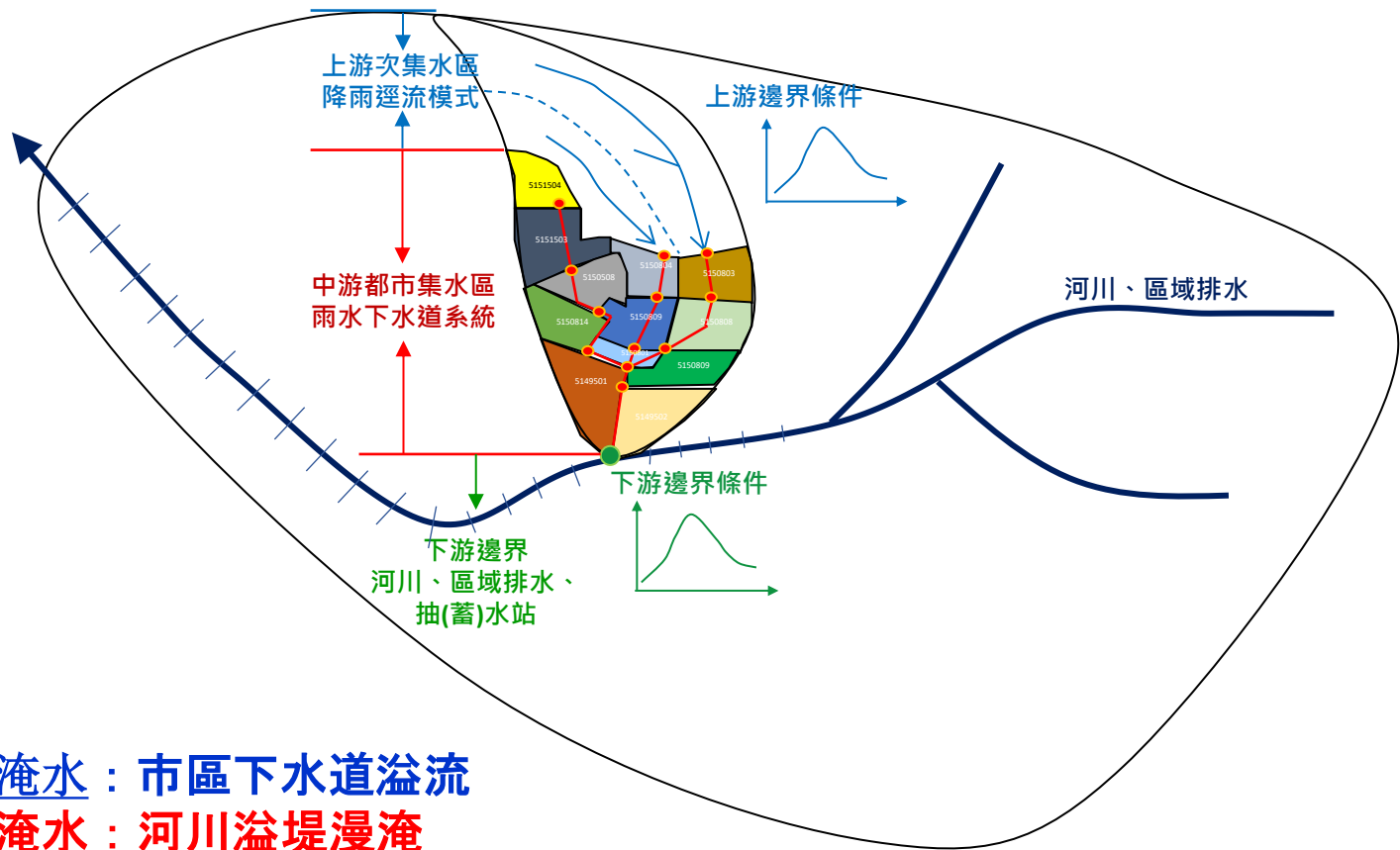
內水淹水：市區下水道溢流
外水淹水：河川溢堤漫淹

一維下水道/一維街道模式(1D/1D model)

- 高強度降雨時期，下水道系統滿載，水流將由人孔溢淹至街道，循街道路網系統漫流。
- 可考慮空間降雨分布、上游邊界條件、下游邊界條件
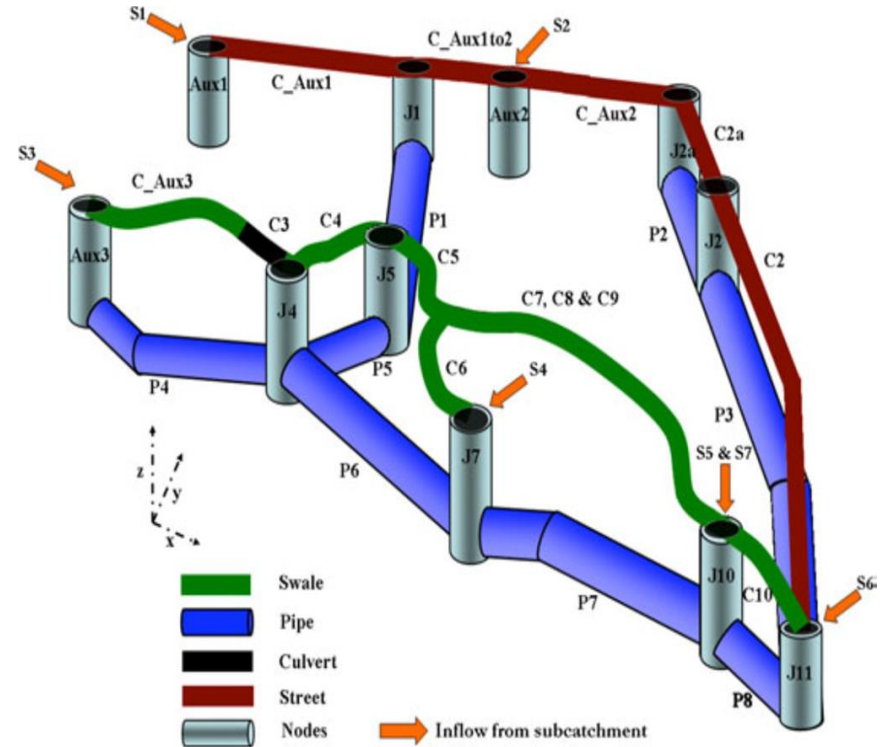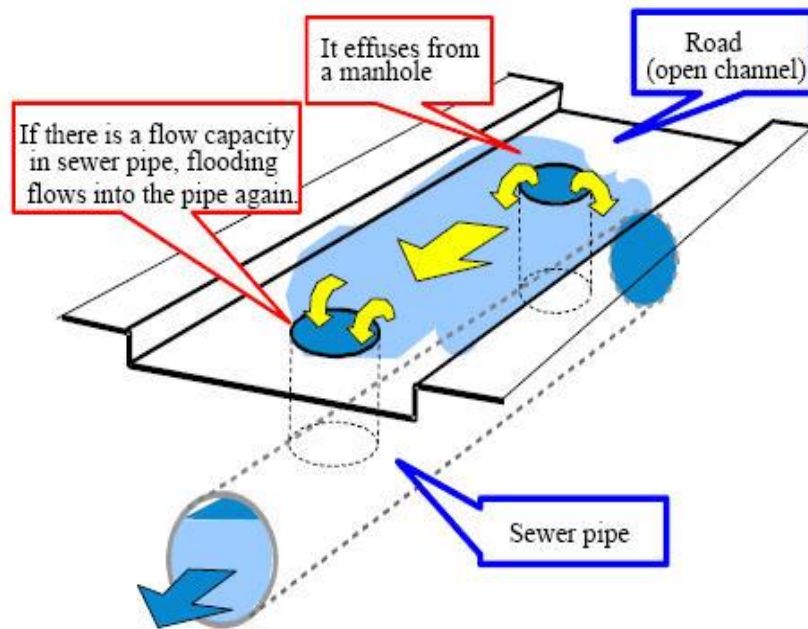
低衝擊開發設施

滲透草溝、綠地

滲透陰井
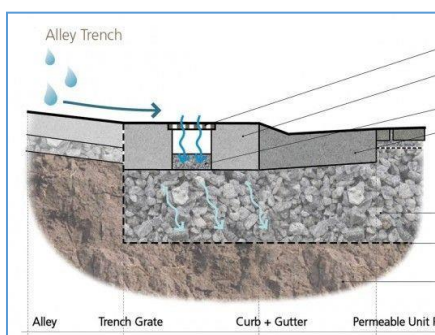
滲透側溝

滲透排水管

屋頂綠化

貯留池
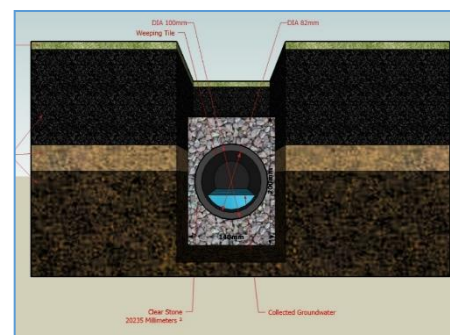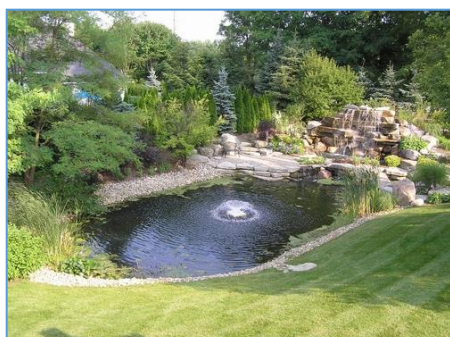
透水舖面
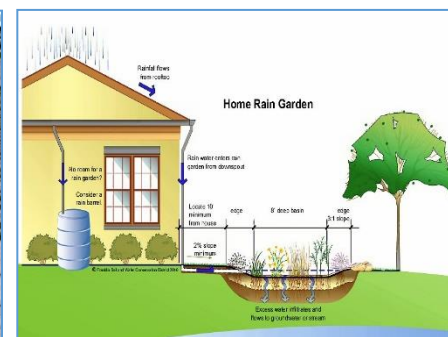
雨花園

都市低衝擊開發設施規劃與管理

建築師進行低衝擊開發設施設計規劃

地方政府執行出流管制
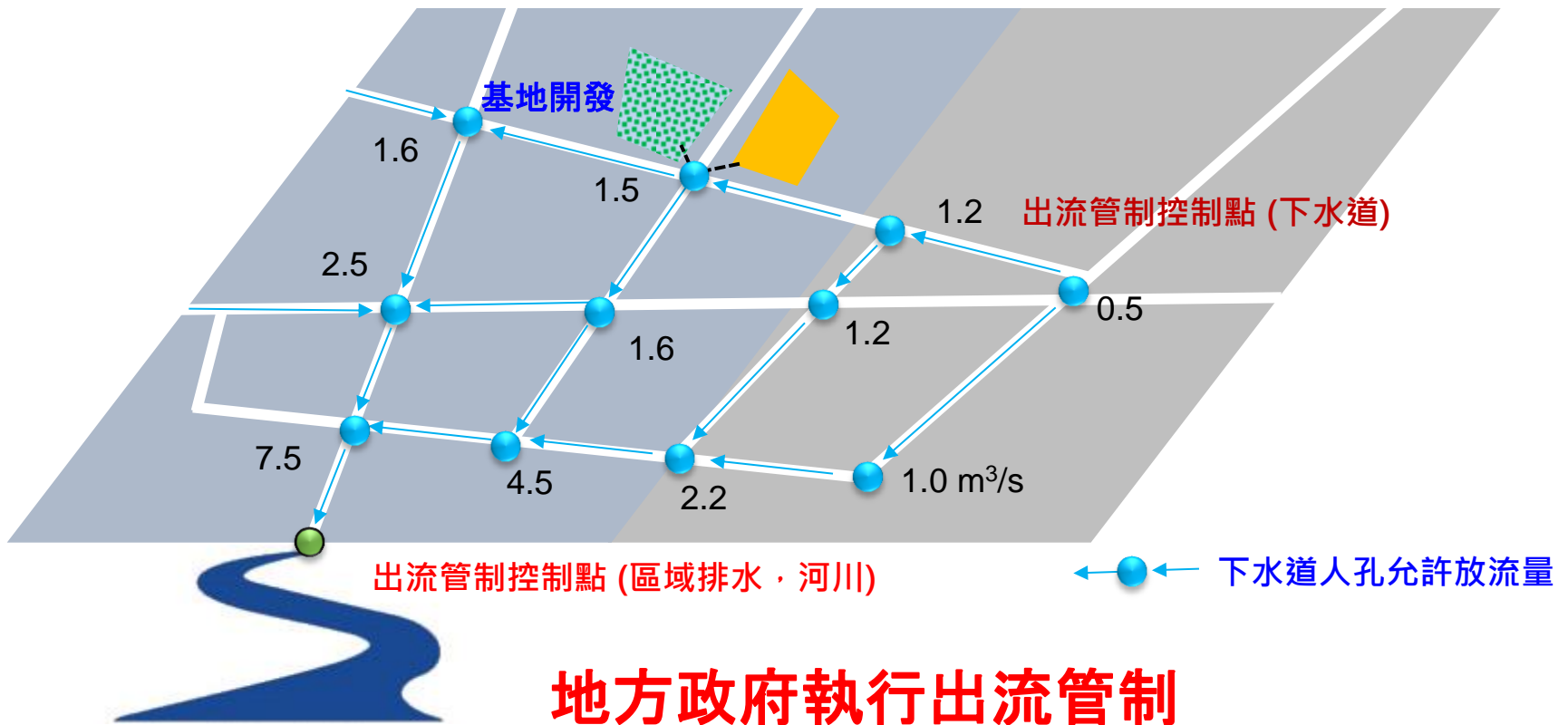
LID facility design and management platform

Account log in > Projects > GIS Inf. > Design > **Hydro.** > Results

水文分析方法：
- 設計雨型
- 保水設計容量
- 合理化三角形單位歷線模式

檢核依據：
- 貯留標準
- 放流標準
- 保水標準
- 總合治水標準

LID: low-impact-development,

LID facility design and management platform

成果表單

Basic datasets for disaster prevention

LiDAR Datasets

(LIght Detection And Ranging)
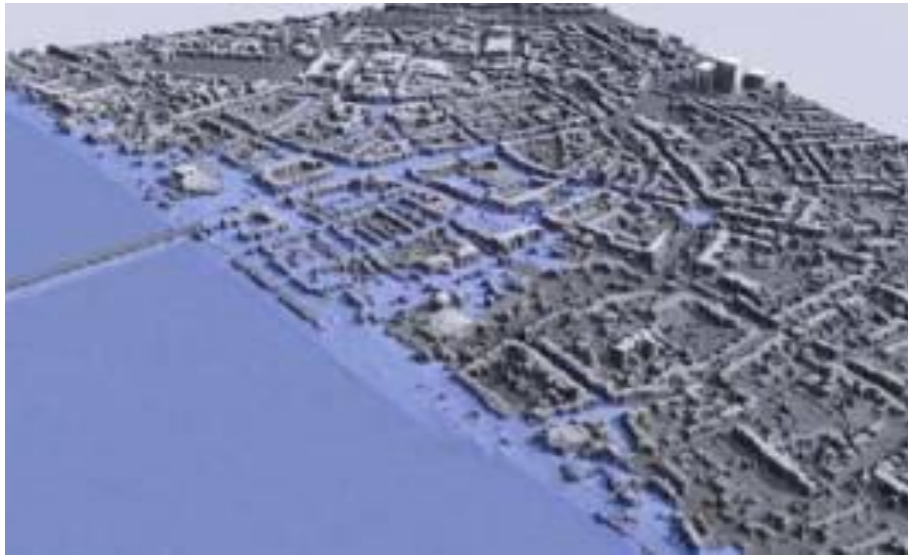
Airborne LiDAR

Vehicle LiDAR