Urban Flood Management:
increasing risks and mitigation measures

Speaker: LIU Jiahong

State Key Laboratory of Water Cycle and Water Security,
China Institute of Water Resources and Hydropower Research (IWHR)

January 27th, 2026

State Key Laboratory of Water Cycle and Water Security, IWHR, Beijing

Contents

01 Urban Floods Under Changing Environment

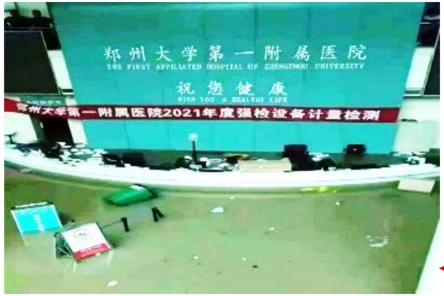
02 Main Factors that Cause Urban Floods

03 Adaptation Strategies and Mitigation Measures

04 Conclusions and Prospects

01 Urban Floods Under Changing Environment

Extreme floods in last 5 years



Zhengzhou, July 20, 2021

Beijing, July 31, 2023

Beijing, July 21, 2012

Newyork , Sept. 1, 2021

Rio de Janeiro
Feb. 15, 2022

Valencia, Spain, Oct. 30, 2024

King County, Washington,
Dec. 11, 2025

Derna, Libya, Sept. 11, 2023

Queensland, Feb. 27, 2022
Jan. 10, 2026

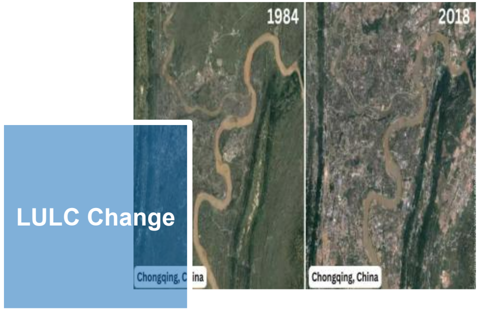
South Asia, Nov. 23, 2025

Multifaceted Environmental Change

- **The increasing urban flood risk is a product of interconnected environmental transformations**
- **Three primary drivers:**

Altered precipitation regimes and sea-level rise

Loss of natural buffering capacity

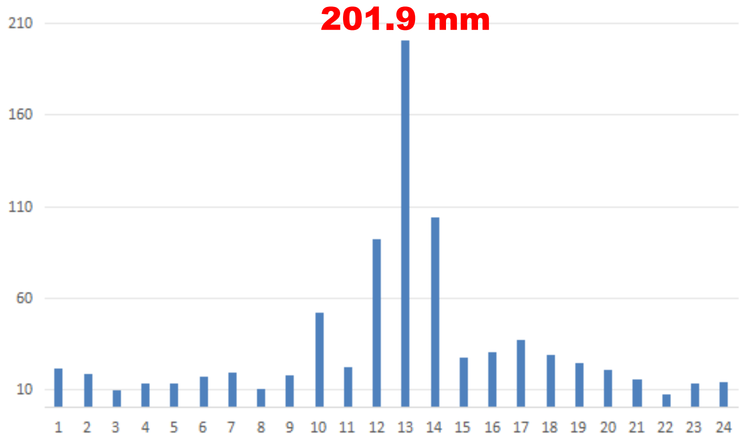


Urbanization-induced surface transformation

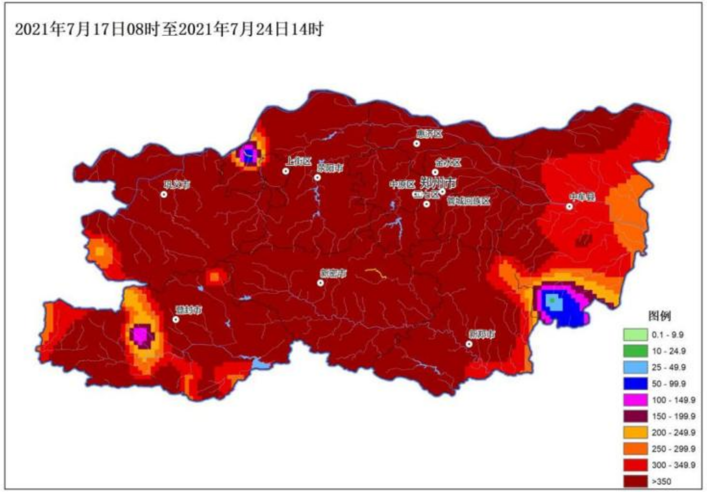
Driver 1:Hydroclimatic Intensification (Precipitation)

➢ **Zhengzhou Case (2021): The maximum rainfall in one hour reached 201.9 mm.**

The maximum rainfall in 24 hour exceeds 624 mm.



Observed hourly rainfall in Zhengzhou on July 20th, 2021

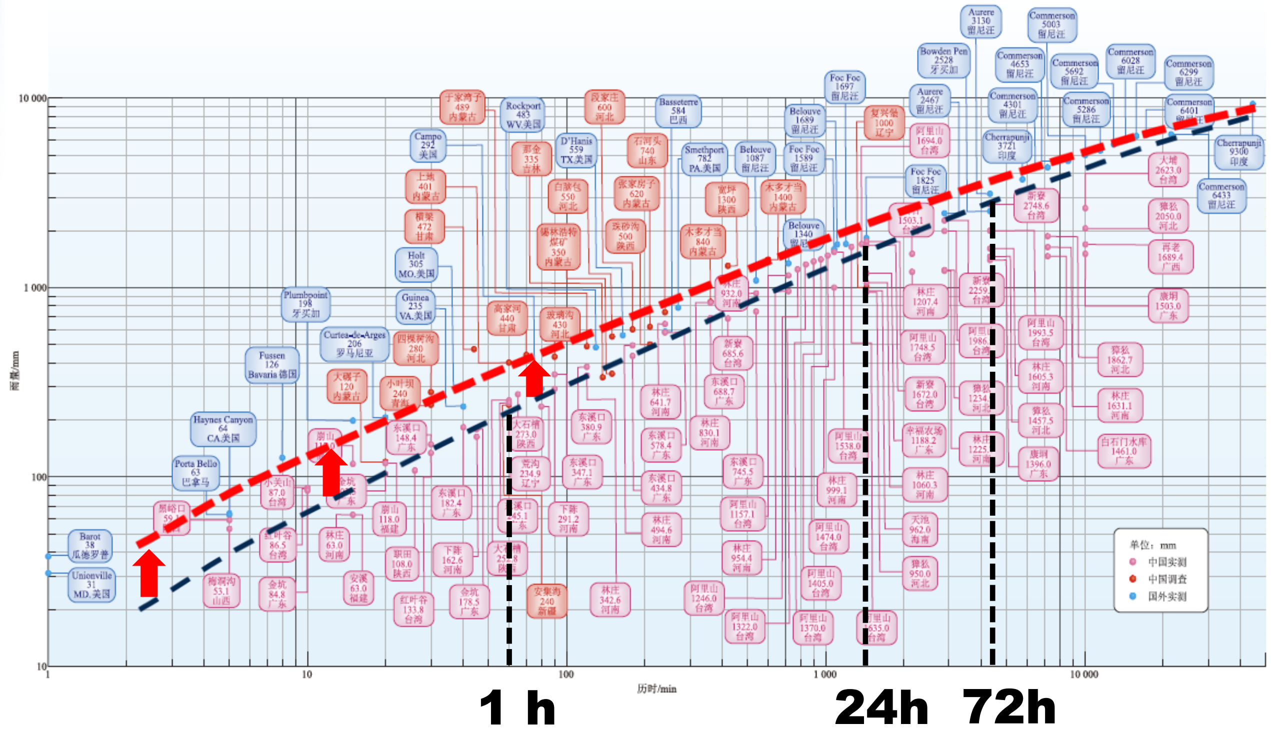


The rainfall distribution of July 20 flood event

P (mm)

Driver 1:Hydroclimatic Intensification (Precipitation)

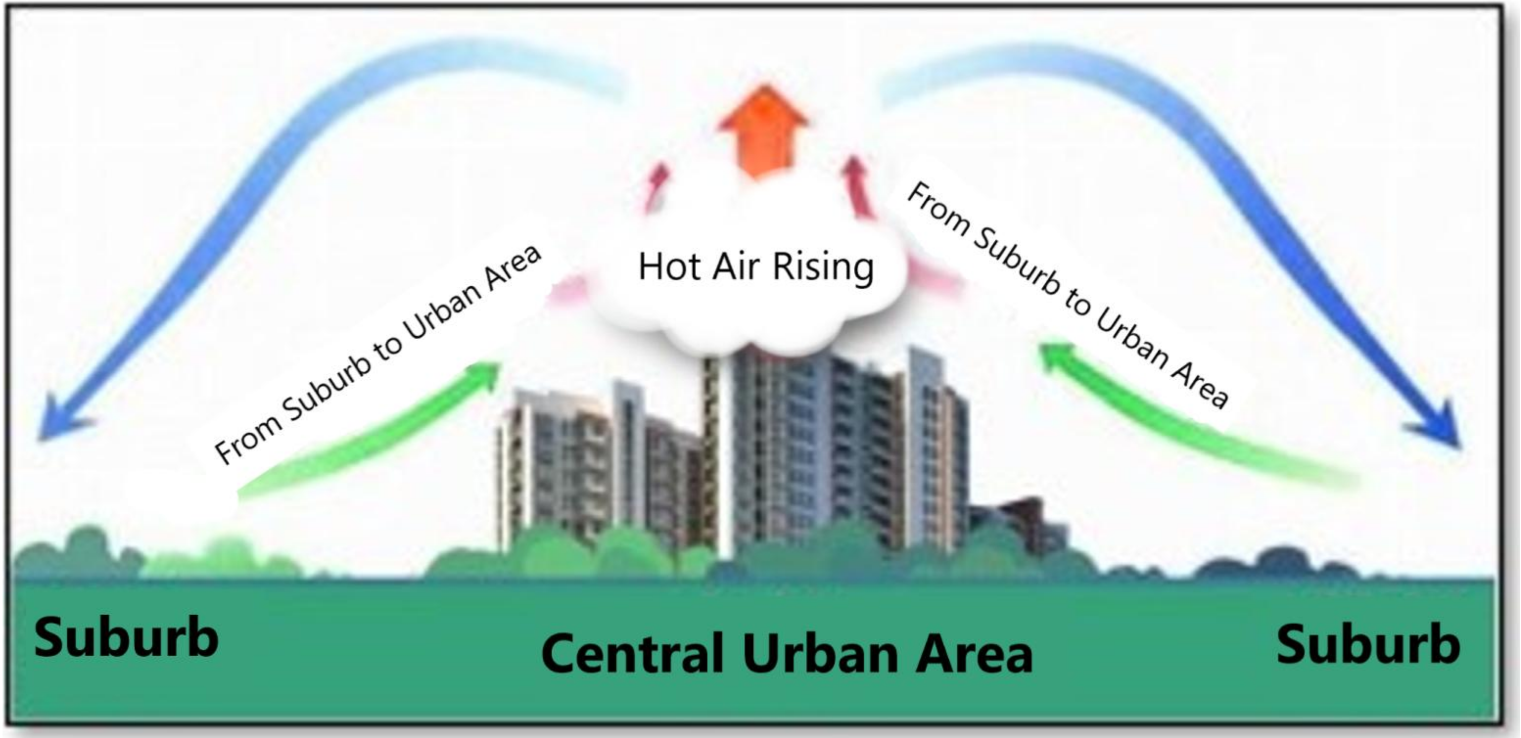
➢ **Observed Extreme Rainfall Events: Duration from 5 min- one month**



- Observed in China
- Surveyed by China
- Observed in other countries

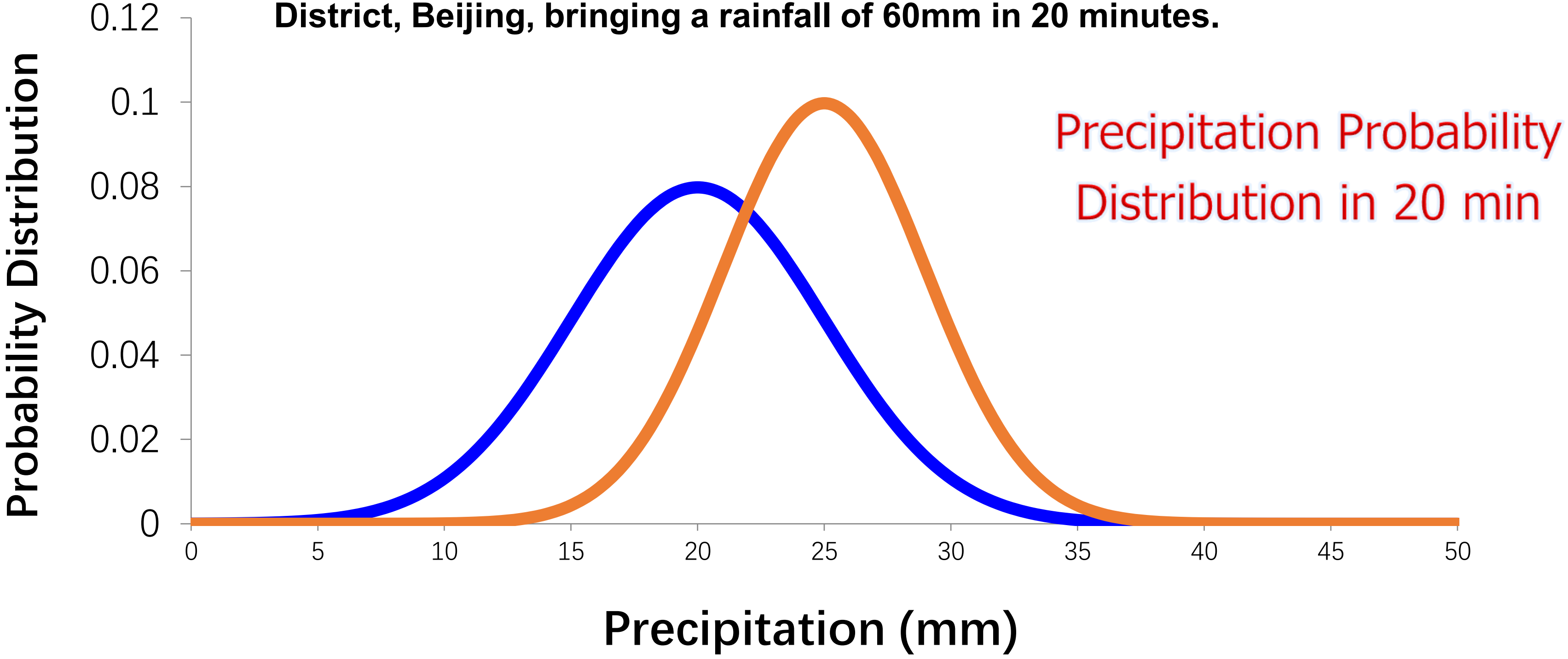
Driver 1:Hydroclimatic Intensification (Precipitation)

The extreme precipitation increased significantly, which increase risks of urban flood



Driver 1:Hydroclimatic Intensification (Precipitation)

At about 21:00, August 16, 2021, a small-scale severe convective phenomenon called as "Supercell Storm" occurred in Haidian District, Beijing, bringing a rainfall of 60mm in 20 minutes.



Driver 1 :Quantitative Analysis in Haikou

- **Analysis of ETCCDI indices reveals consistent intensification of extreme precipitation:**

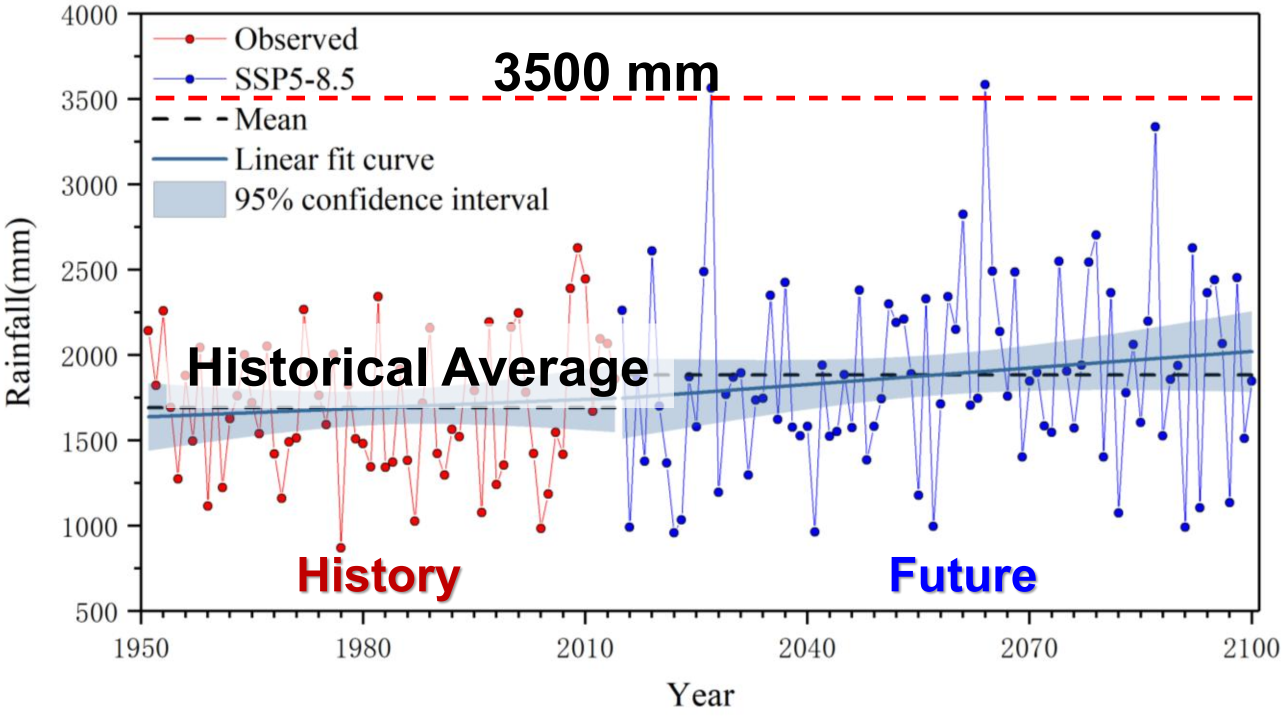
• **Rx1day (Max 1-day rainfall):** Increasing
• **SDII (Daily Intensity Index):** Significant increase
• **R95p (Very wet days):** Increasing trend
• **R25mm (Heavy rain days):** Significant increase

Not just more rain, but more intense, concentrated rainfall

Period	CDD	CWD	R25mm	R95P	R99P	Rx1day	Rx5day	SDII
2071-2100	36	7	21	652	251	211	304	17
2051-2070	31	6	26	762	274	204	328	19
2031-2050	38	6	18	550	215	190	290	16
2021-2030	42	7	19	577	189	159	271	16
1951-2020	34	8	20	537	191	161	256	16

Driver 1 :Quantitative Analysis in Haikou

- The average rainfall in the future decades will be **196 mm** more than the rainfall in the historical period

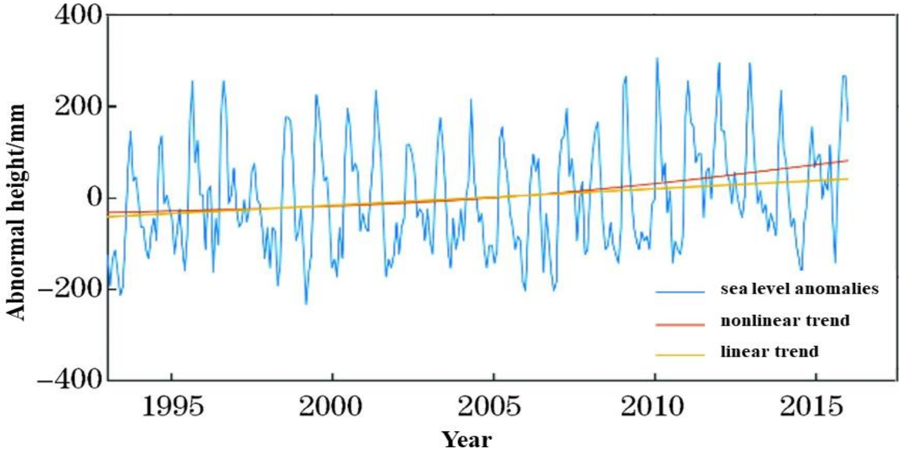


Variation of rainfall from 1951 to 2100 in Haikou

Driver 1: Hydroclimatic Intensification (Sea-Level Rise)

- **A critical amplifier of risk for coastal megacities.**
- **Data indicates a 113 mm rise in sea level in Hainan since 1980s, significantly exceeding the average rise of 90 mm.**
- **Impacts: Elevates groundwater tables, reduces drainage gradient efficacy, and exacerbates compound flooding events.**

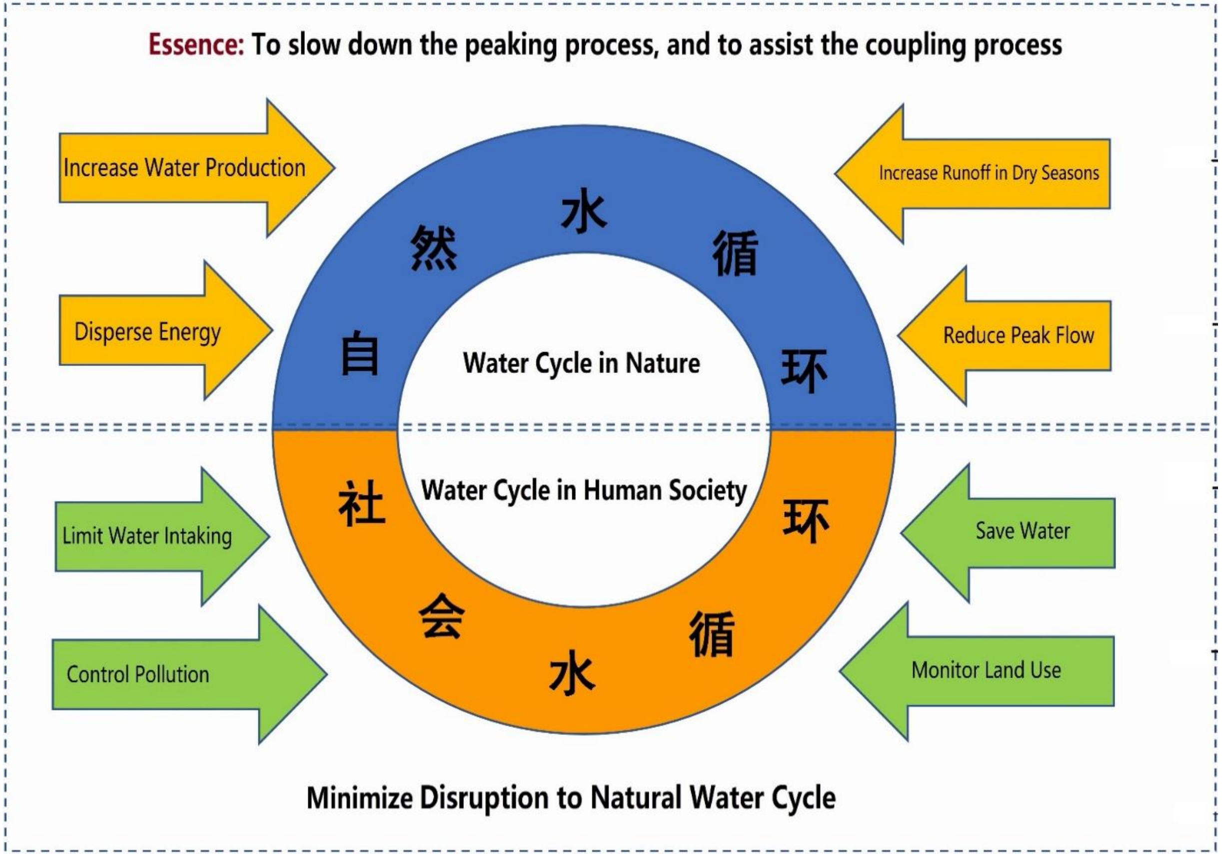
The road was submerged during storm surge

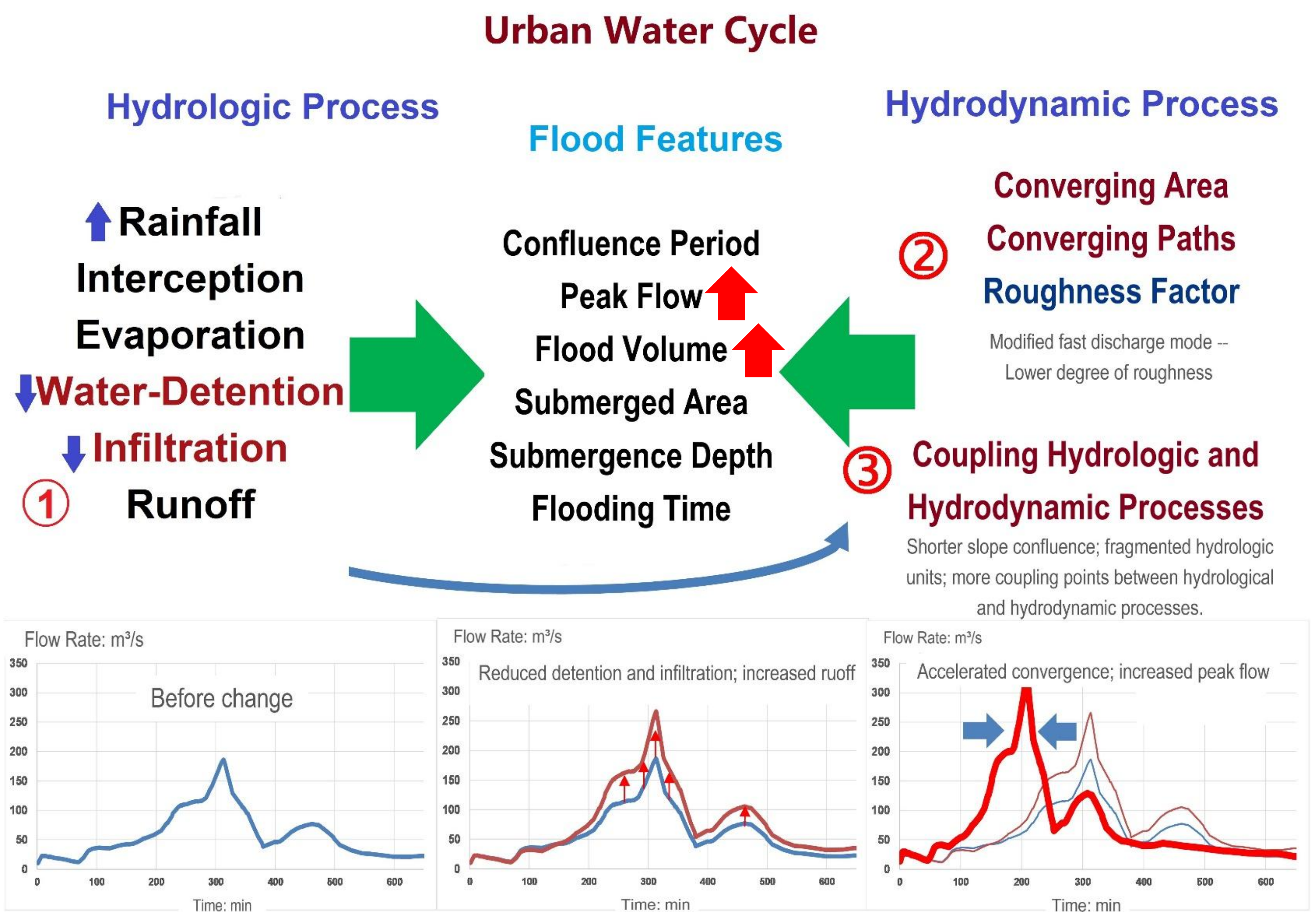


Variation trend of sea level height at Hong Kong tide gauge

Driver 2: Hydrological System Degradation

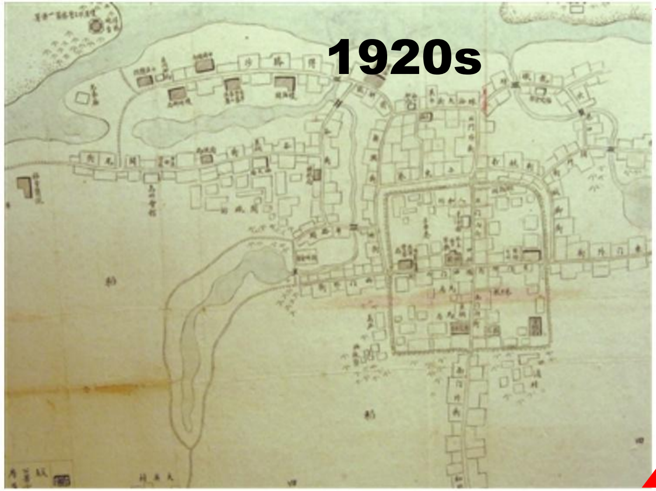
- **Urban development often entails the loss of natural hydrological features.**
- **Encroachment or filling of: Natural watercourses, wetlands, lakes, and depressions.**
- **These natural elements provide essential ecosystem services for stormwater retention, detention, and conveyance.**

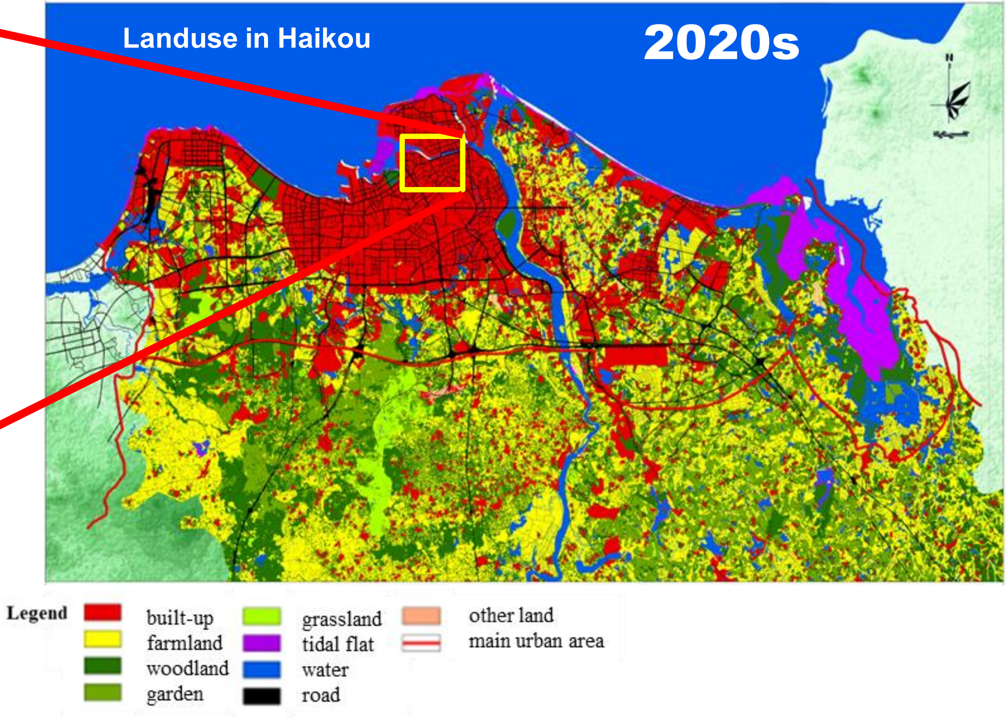



Urban Water Cycle
Hydrologic Process
Flood Features
Hydrodynamic Process
Rainfall
Interception
Evaporation
Water-Detention
Infiltration
① Runoff
Confluence Period
Peak Flow
Flood Volume
Submerged Area
Submergence Depth
Flooding Time
② Converging Area
Converging Paths
Roughness Factor
Modified fast discharge mode --
Lower degree of roughness
③ Coupling Hydrologic and
Hydrodynamic Processes
Shorter slope confluence; fragmented hydrologic units; more coupling points between hydrological and hydrodynamic processes.
Flow Rate: m³/s
Before change
Time: min
Flow Rate: m³/s
Reduced detention and infiltration; increased ruoff
Time: min
Flow Rate: m³/s
Accelerated convergence; increased peak flow
Time: min

Driver 3:Land Use and Land Cover (LULC) Change

- **Impervious Surface:** Urbanization replaces permeable soils with impermeable materials.





- **Impact on Runoff Coefficients**: Transforms a landscape from high-infiltration to high-runoff, drastically increasing peak discharge volumes.

02 Main Factors that Cause Urban Floods

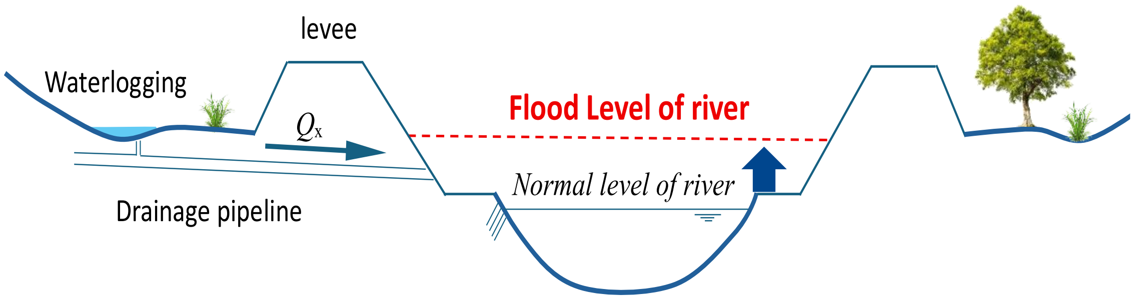
Why does the urban flood disaster happen?

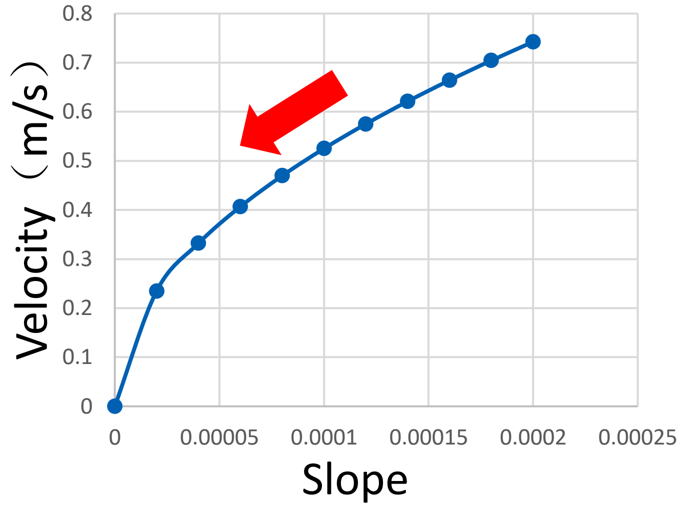
Factor 1: Encounter of river flood and urban storm

Urban flooding usually happens when an external river flood encounters the city's internal storm-waterlogging.

Why does the urban flood disaster happen?

Factor 1: Encounter of river flood and urban storm



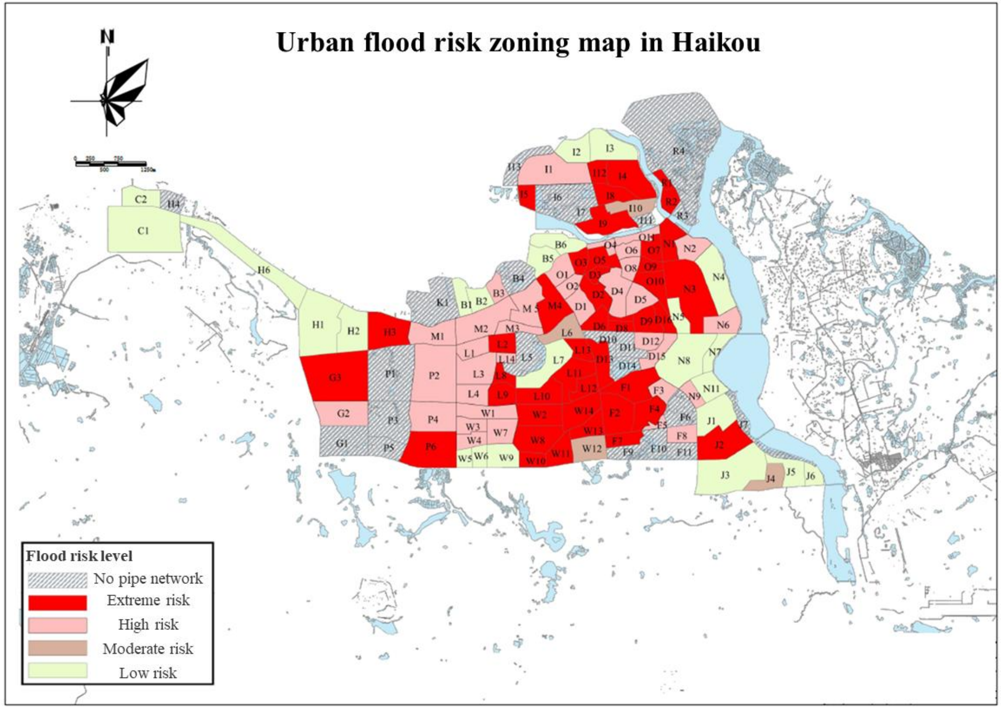


The hydraulic slope of the drainage network decreases along with the rise of river water level. The drainage capacity of the city will sharply decrease.

Factor 2: Overwhelmed Drainage Systems

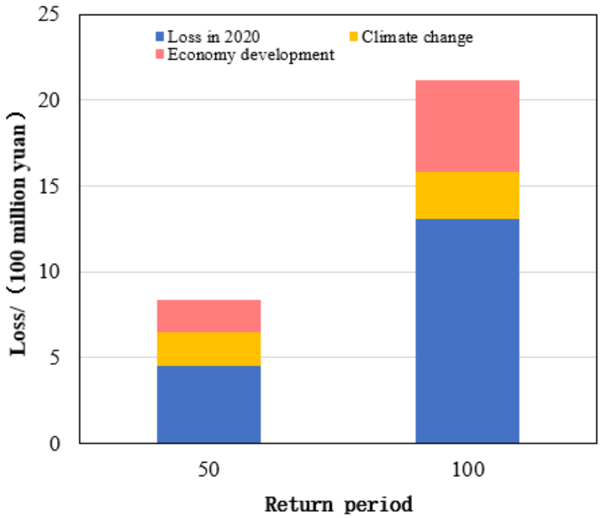
- **Inadequate Drainage Capacity:** Systems are often outdated, undersized for current rainfall intensities, and lack complete spatial coverage.

- **Evidence from Haikou:** Extreme and high-risk areas are concentrated in the city center, which used to be the old castle and the drainage system is outdated.

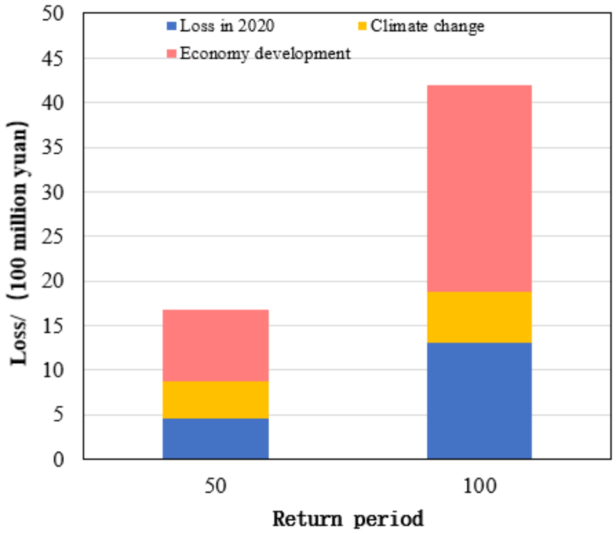


Factor 3: Concentrated Exposure & Economic Paradox

- Economic development paradoxically increases potential losses by concentrating high-value assets in hazard zones.
- Critical Finding from Haikou: Future socio-economic development is projected to be the **primary driver** of increased flood losses, exceeding the impact of climate change itself by 2035.



2025



2035

03 Adaptation Strategies and Mitigation Measures

Three-Pronged Approach

Urban Planning ⟷ **Infrastructure Design** ⟷ **Emergency Management**

- **Urban Planning:** Sponge City concepts, land-use zoning
- **Infrastructure Design:** Blue-Green-Grey infrastructure integration
- **Emergency Management:** Forecasting, warning, regulation systems

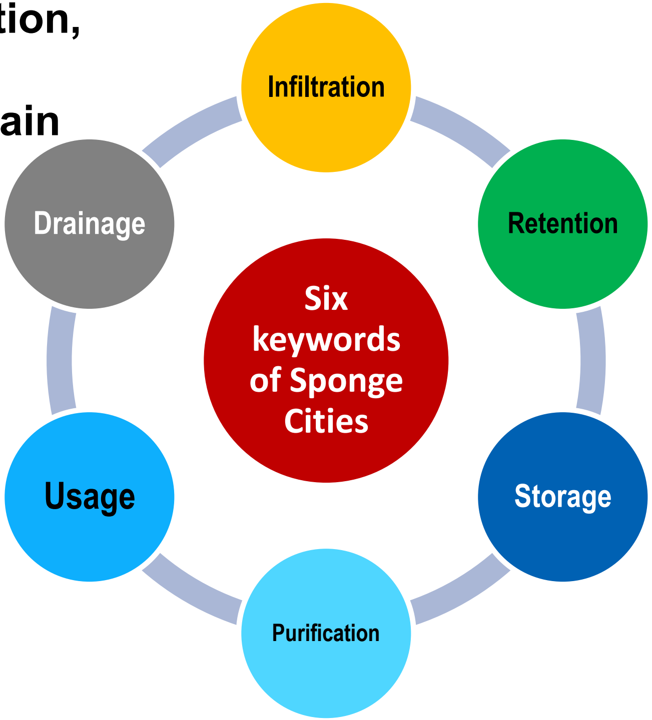
Move from reactive control to proactive risk management

Planning: Nature-Based Solutions & Sponge City Concepts

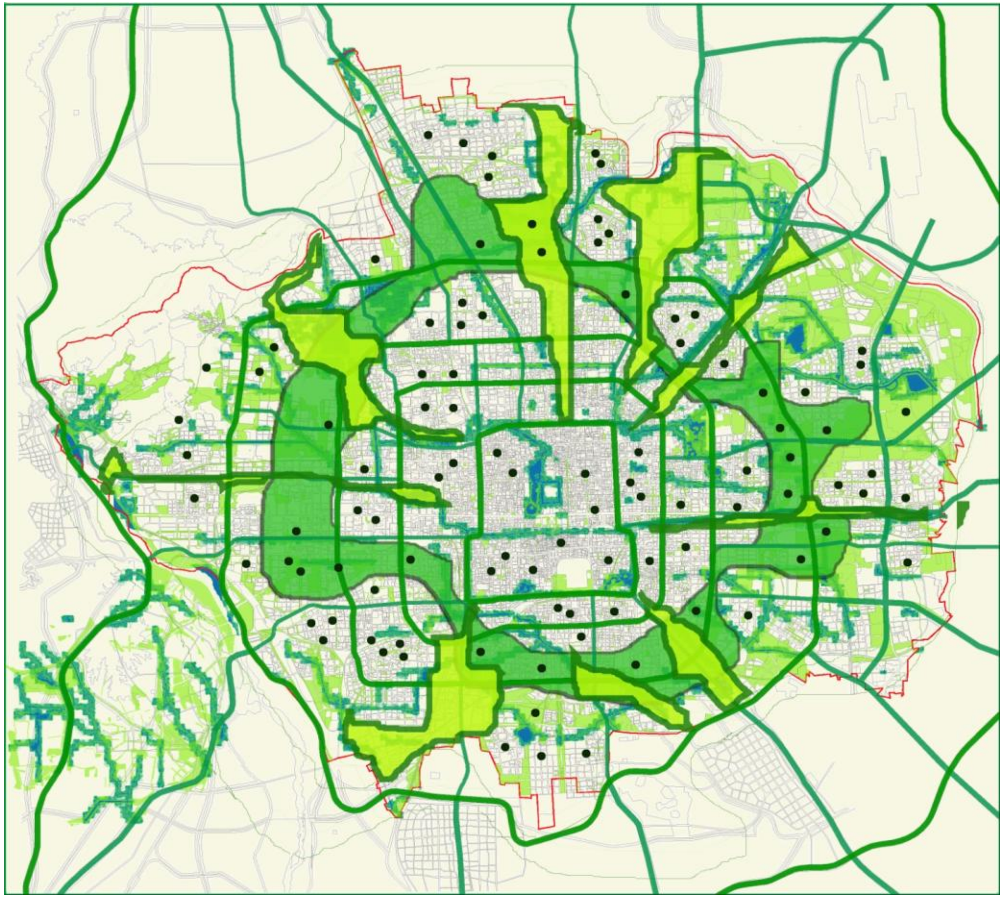
- **Principle:** Restore the natural hydrological functions of the urban landscape.
- **Six Keywords:** Infiltration, Retention, Storage, Purification, Reuse.
- **Measures:** Permeable pavements, bio-retention cells, rain gardens, rainwater purification wetlands.

Drainage and Retention system in Daxing International Airport

- Designed rainfall: **144mm**
- Exceeding the amount of 24h rainfall that happens once in 3 years

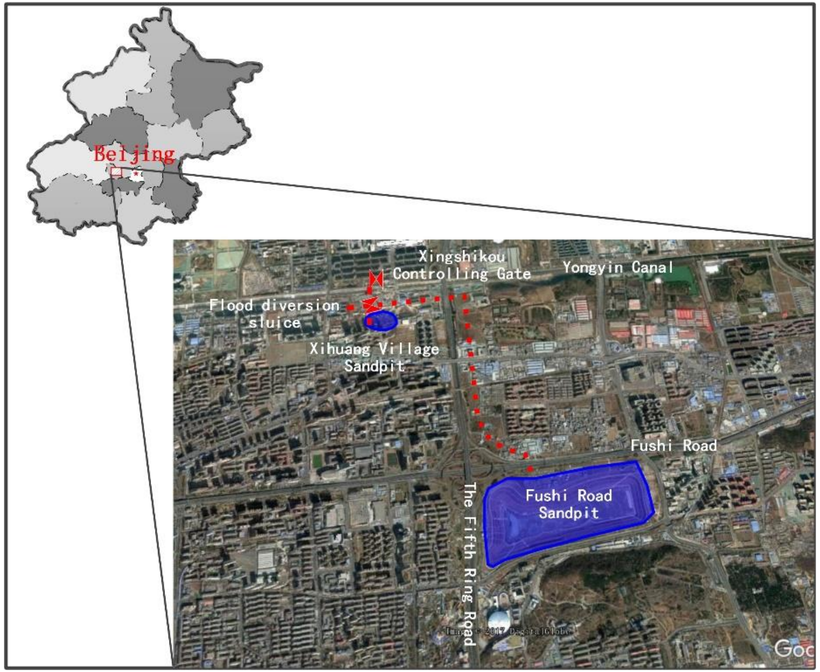


Green Facilities for Water Storage



In Beijing, **272 major rainwater storage projects** have been planned in the main city zone, with the storage capacity of about **23,000,000m³**.

Construction of Water Storage Project in Western Beijing

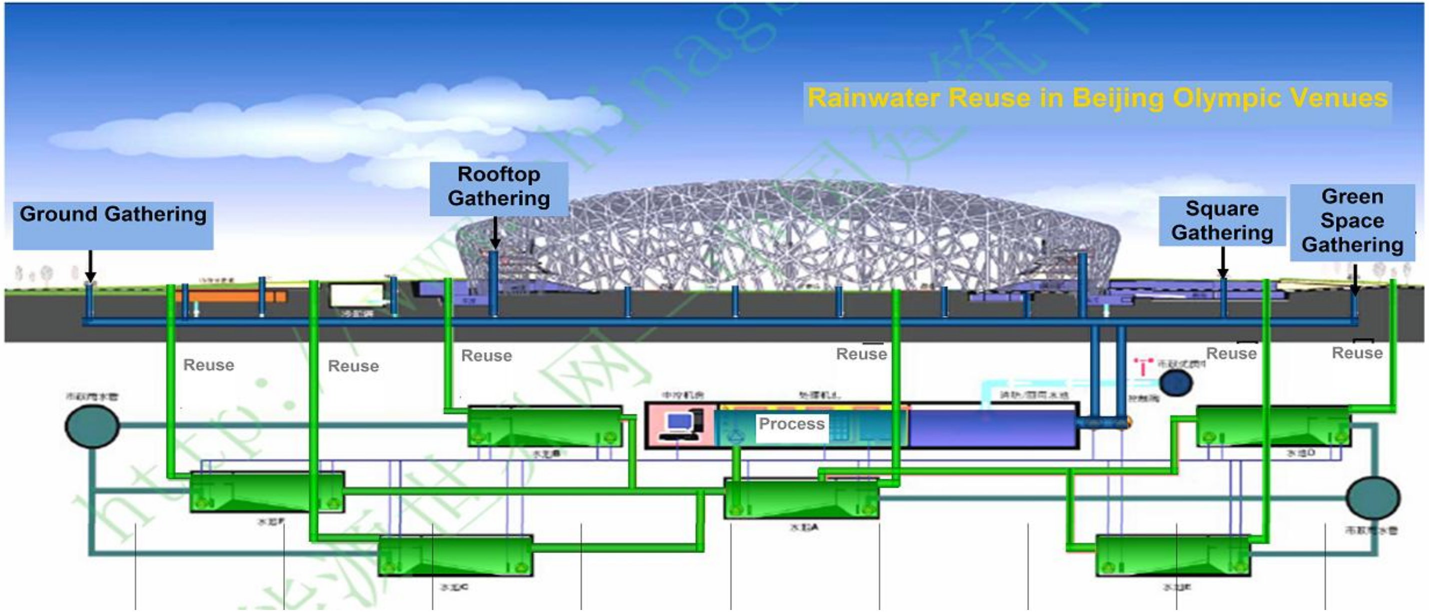


Construction of Water Storage Project in Western Beijing

Design: Rainwater reuse system in Beijing Olympic Park

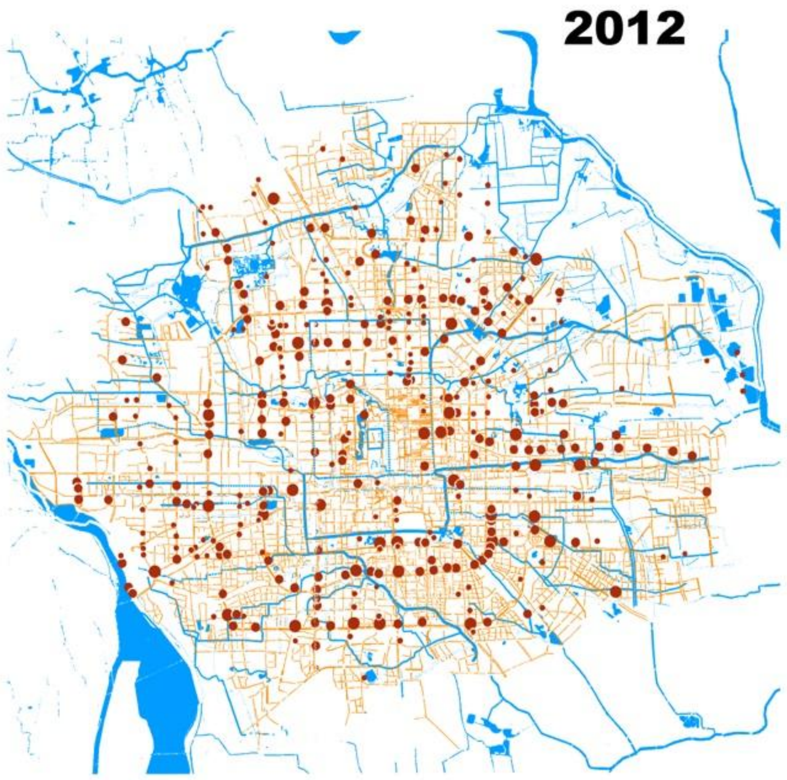
Case 1: Infrastructure Design of Beijing Olympic Park Sponge System

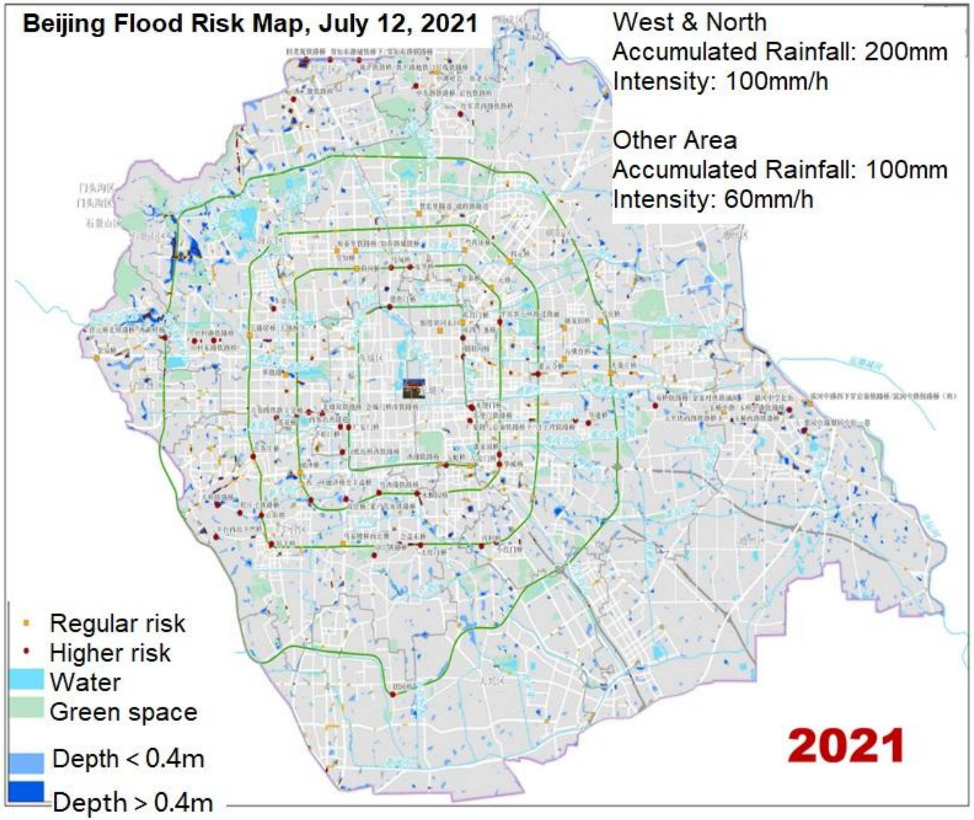
- All rooftops, ground, and green space were equipped with rainwater harvesting and retention facilities.
- Annual Storage Capacity: ~1,050,000 m³.
- Able to retain rainfall events with a 20-year return period within the park boundaries.



Design: Engineered Grey Infrastructure

Case 2: underground storage





Design: Engineered Grey Infrastructure

- **Tunnels & Pipelines:** Wuluju Double Pipelines (3m diameter)
- **Distributed Storage:** Underground tanks at strategic locations

Interior of Yongdingmen Storage Tank

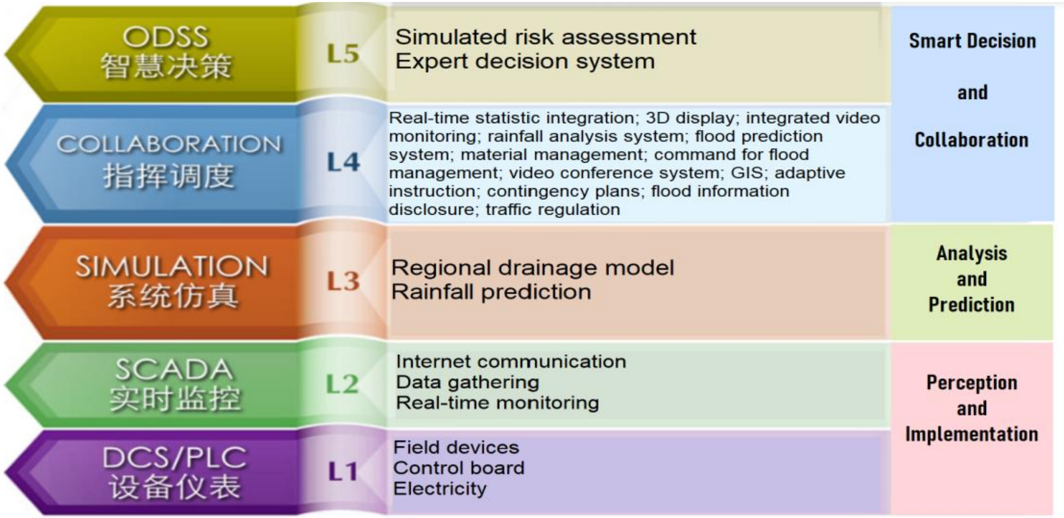
Interior of Chengshousi Storage Tank (storing 50cm of water)

Interior of Southwest 3rd Ring Storage Tank

Interior of Wuluju Double Pipelines (3m in diameter)

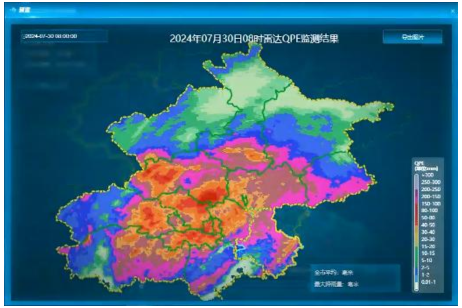
Management: Smart Water Management & Digital Twins

- **Sensing & Monitoring:** Real-time data acquisition (IoT) (1st and 2nd levels)
- **Modelling & Forecasting:** Hydrological/hydraulic digital twins for scenario analysis (3rd level)
- **Decision Support & Control:** Integrated platforms for optimizing, decision making and command executing (4th and 5th levels)

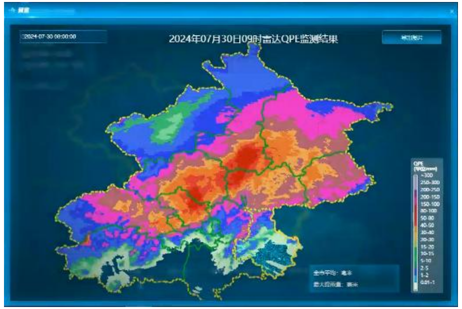


Management: Smart Water Management & Digital Twins

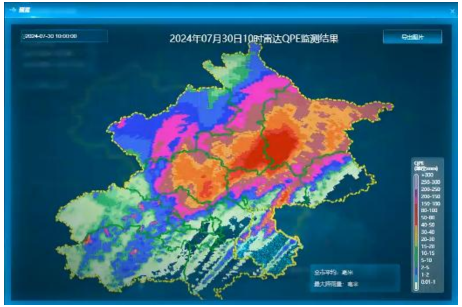
L1 & L2: Real-time data acquisition and telecommunication



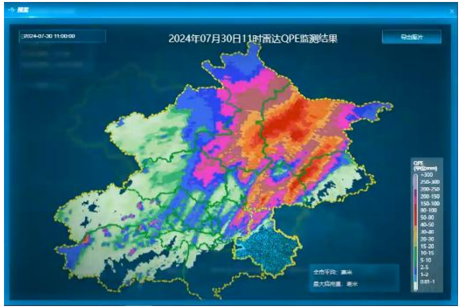
QPE at *08:00* July 30, 2024



QPE at *09:00* July 30, 2024



QPE at *10:00* July 30, 2024

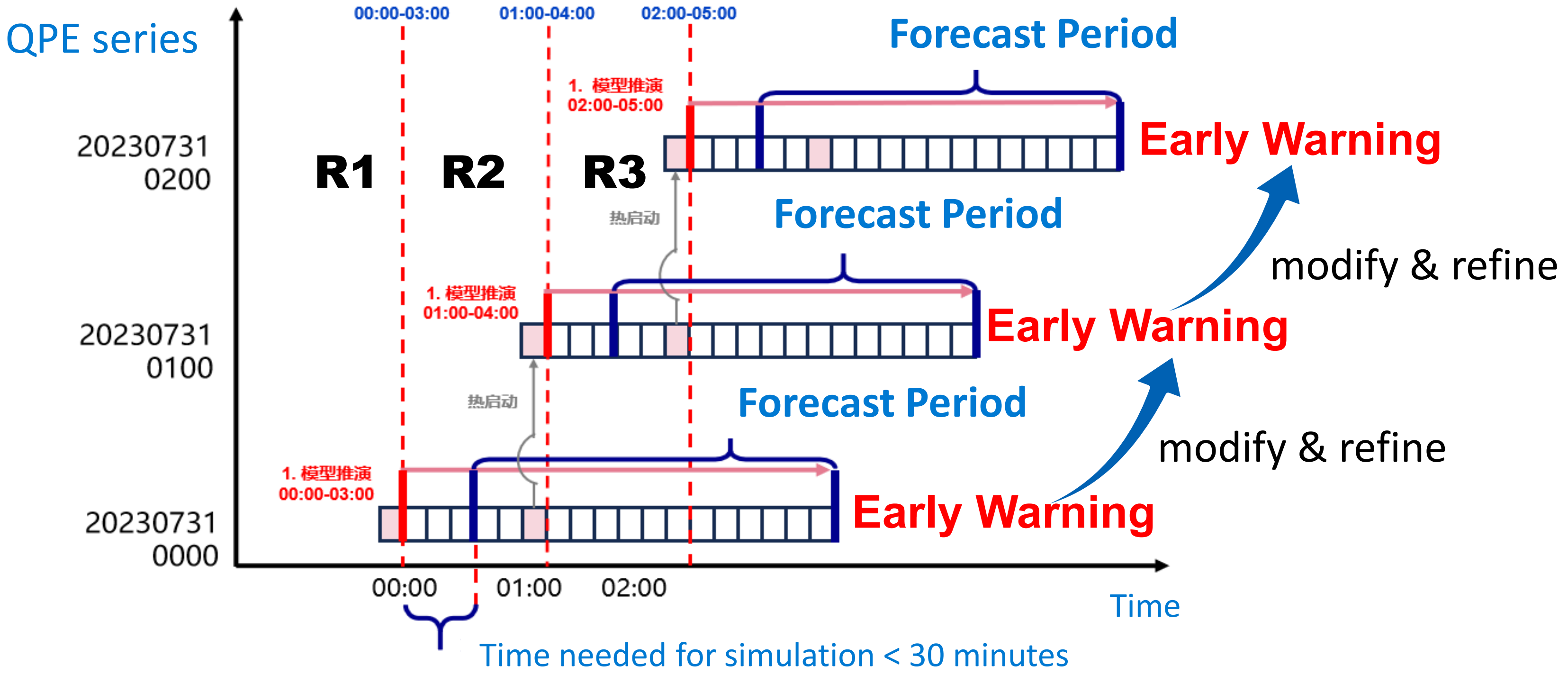


QPE at *11:00* July 30, 2024

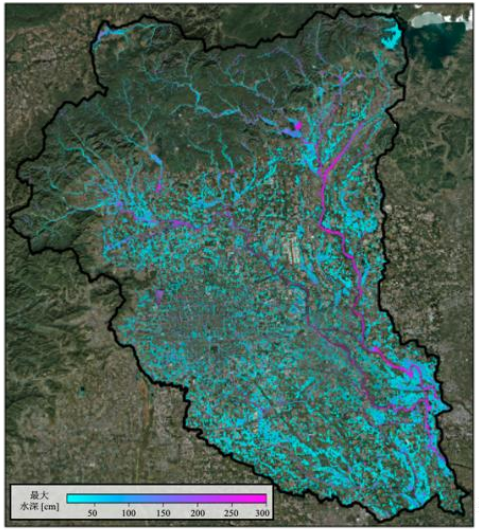
The QPE monitored by Radar during 08:00-11:00 am, July 30, 2024

Management: Smart Water Management & Digital Twins

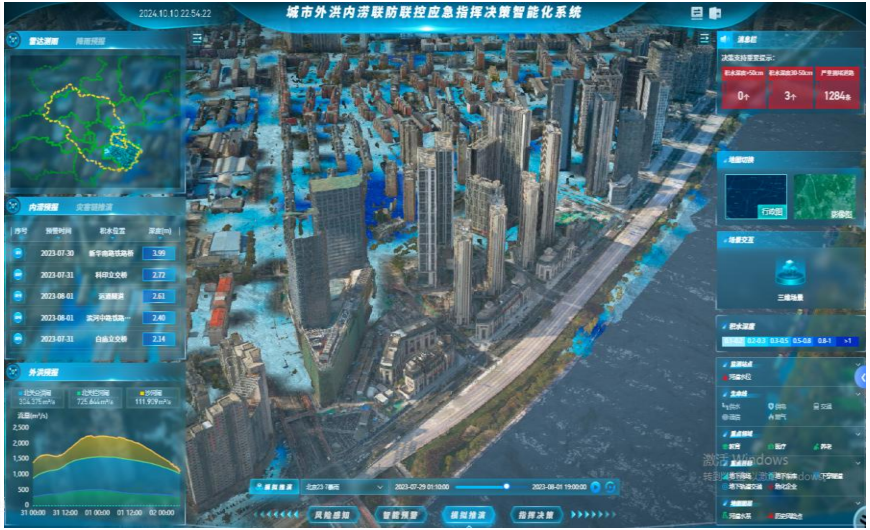
L1 & L2: Modelling & Forecasting



Management: Smart Water Management & Digital Twins



Flood risk map



Community scale flood risk assessment
(based on Digital Twins)

Flood risk classification
(Red/Orange/Yellow)

Management: Smart Water Management & Digital Twins

The decisive question for policymakers is not just technical feasibility, but economic necessity

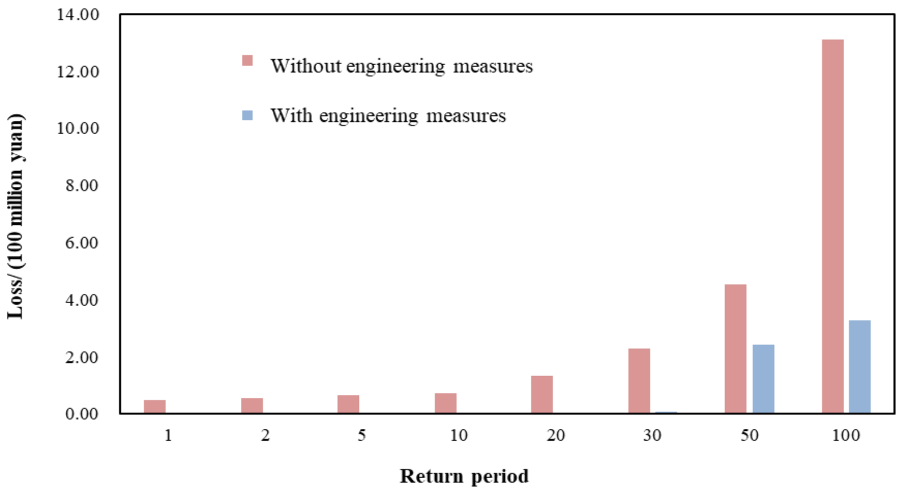
Cost of Inaction vs. Cost of Action

From "What Can We Do" to "Why We Must Do It"

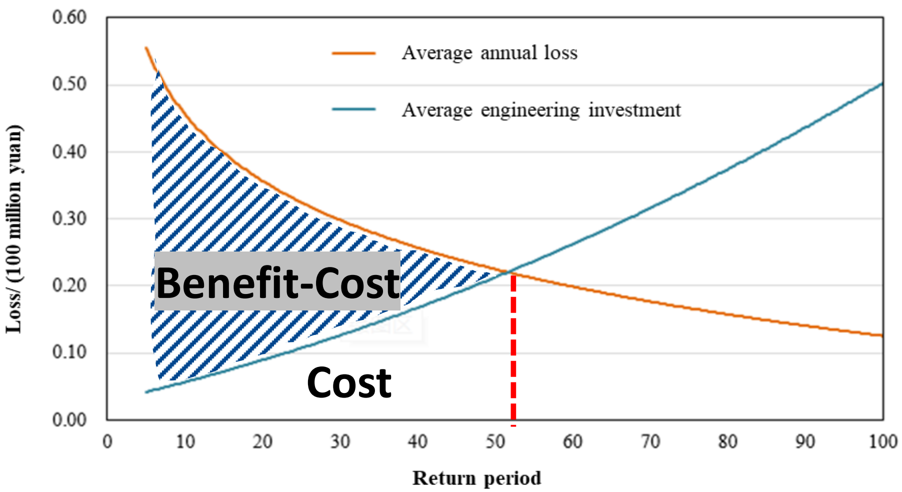
Management: Cost-Benefit Analysis

➢ **Key Findings from Haikou:**

- **For high-frequency events (<50-year return period), engineering measures are highly cost-effective (Benefit-Cost > 0).**
- **For low-probability, high-impact events, the cost of structural protection may be not cost-effective, favoring risk-transfer mechanisms (e.g., insurance).**



Comparison of flood losses with or without engineering measures



Comparison between engineering investment and loss

04 Conclusions and Prospects

Key Conclusions

Hazard Intensification — Climate change and urbanization synergistically increase flood risk

Vulnerability Concentration — Economic development paradoxically increases potential losses

Integrated Solutions — Green-grey-smart infrastructure combination is essential

Prospects

Mitigation

- With a systematic consideration of the ecological environment, measures for mitigation should be prioritized.

Engineering Measures

- Engineering measures are the most widely applied strategies nowadays. They are especially useful for floods with high frequency and short return period.

Risk Transfer

- In order to manage floods with low frequency and long return period (catastrophes causing great loss), it is recommended to adopt economic measures such as risk transfer.

Thanks for your attention!

Acknowledgement: IWHR-CRR Project Members

LIU Jiahong
Senior Engineer
Deputy Director

Member of National "10000 Talents Plan" and National Sponge City Technical Expert Group

SHAO Weiwei
Senior Engineer

Project leader of the key national research and development program "Dynamic Flood Risk Assessment in Highly Urbanized Areas"

MEI Chao
Senior Engineer

Doctor, winner of national scholarship and Excellent Paper Award of China Natural Resources Society

WANG Jia
Senior Engineer

Doctor, winner of national scholarship, outstanding graduate of Beijing City

SU Xin

GAO Han

LIU Chuang

LU Jiahui

WANG Dong

ZHANG Dongqing

YAN Wenchang

ZHAO Ying

LUO Zhuoran