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Toward a resilient coastal city:

performance assessment for adaptive solutions of green-gray-blue infrastructure

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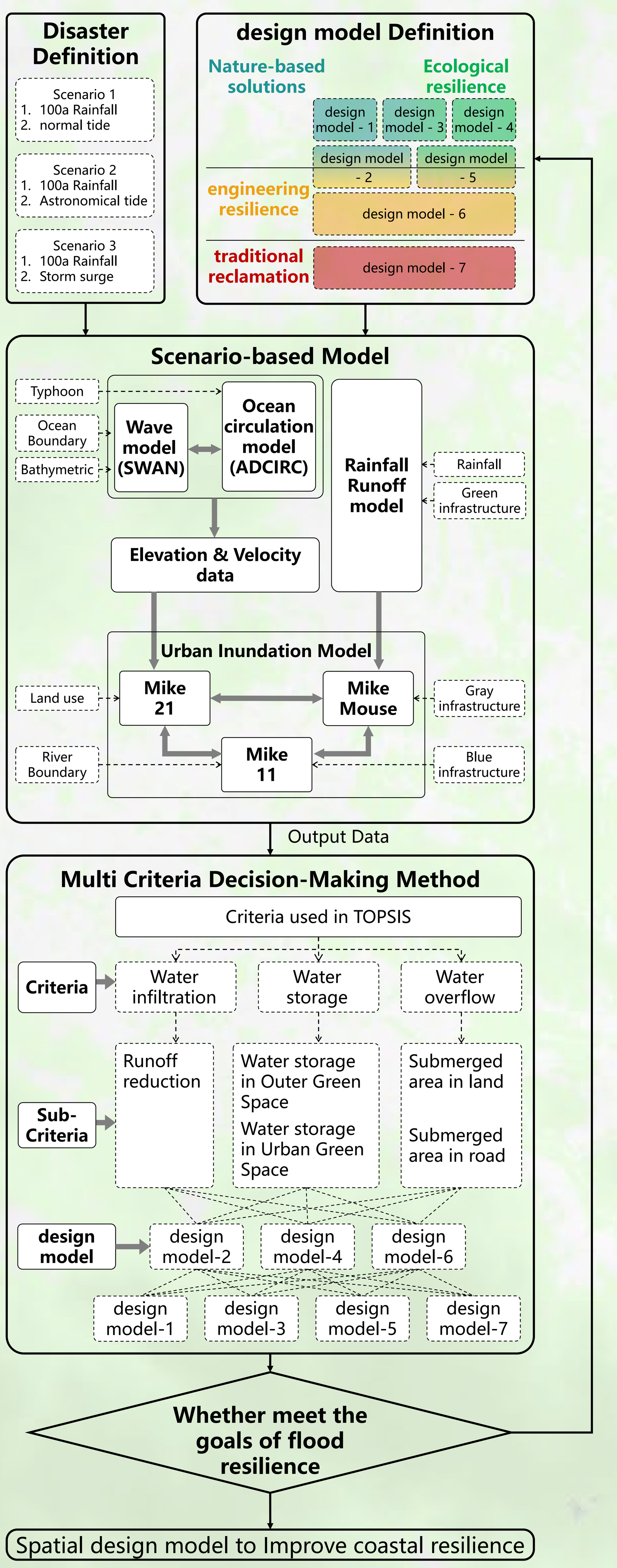
I. Introduction

- The low-elevation landform make coastal area, especially **the Guangdong-Hong Kong-Macao Greater Bay Area (GBA)**, more vulnerable to **heavy rainstorms** and **surge storm** in the future.
- **Resilience city** is an emergent concept applied in urban design model, and disaster management to deal with coastal hazards, such as **urban flooding**.
- Some measure, such as **Nature-based solutions, ecological and engineering resilience, adaptive strategies** were implemented to improve resilience performance in GBA.
- Policy makers and urban planners need **quantitative method** to assess the **flood risk** and identify the optimal design model.

Research question:

Which concept (or measure) can deal with the coastal disaster by evaluating the performance of Green-Blue-Gray infrastructure ?

II. Methodology



III. Scenario-based Model Simulation

• Disaster Definition

Scenario	Sea Level	rainfall
Scenario1 – Normal tide	Normal tide in 23th Aug (predicted by Tide Model Driver)	100y 24h design rainfall
Scenario2 – Astronomical tide	Astronomical tide in Aug (predicted by Tide Model Driver)	100y 24h design rainfall
Scenario3 – Storm surge	Storm surge in 23th Aug created by Typhoon Mangkhut (predicted by ADCIRC+SWAN)	100y 24h design rainfall

Figure 1 Sea level scenarios

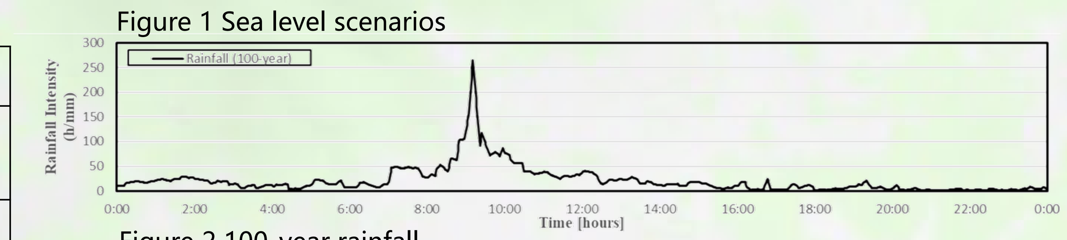
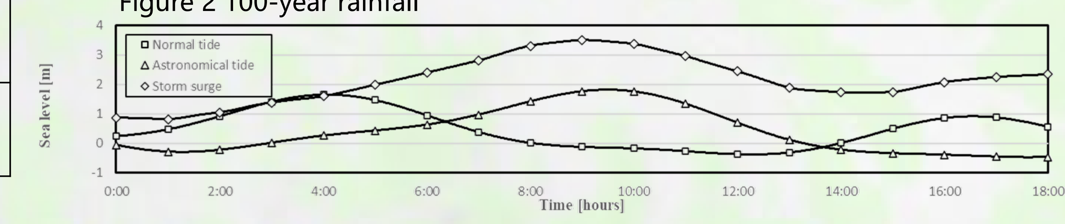


Figure 2 100-year rainfall



• design model Definition

design model	design model-1 (Nature-based solutions)	design model-2 (Nature-based solutions + engineering resilience)	design model-3 (Nature-based solutions +ecological resilience)	design model-4 (ecological resilience)	design model-5 (ecological resilience + engineering resilience)	design model-6 (engineering resilience)	design model-7 (traditional reclamation)
Elevation	Very Low Altitude (4 – 6 m)	Low Altitude (5 – 7 m)	Low Altitude (6 – 8 m)	Middle Altitude (8 – 10 m)	Middle Altitude (7 – 9 m)	High Altitude (9 – 11)	Very High Altitude (10 - 12 m)
Green infrastructure	Nature-based low island	Thin engineering dike + Nature-based low island	Wide ecological resilience dike + Nature-based river space	Wide ecological resilience dike + ecological river space	Thin engineer resilience dike + ecological river space	Thin engineer resilience dike + Urban river space	Thin engineer resilience dike
Blue infrastructure	Wide natural waterways	Wide urban waterways	Wide natural waterways + thin urban waterways	Thin urban waterways	Thin natural waterways	Thin urban waterways	Thin urban waterways

Fig 03-09
Elevation data
-6m
-1m
4m
7m
9m
11m
13m

Fig 10-16
G-B infrastructure
Urban Green Space
Outer Green Space
Controlled Water
Outer Water
Dike

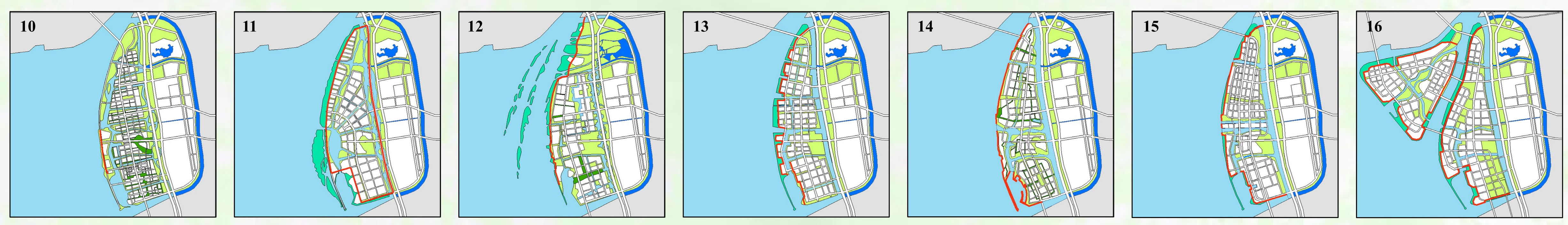


Fig 17-23
Land use data
Residential
Culture
Commercial
Industrial
Green Space
Water
Mixed Use

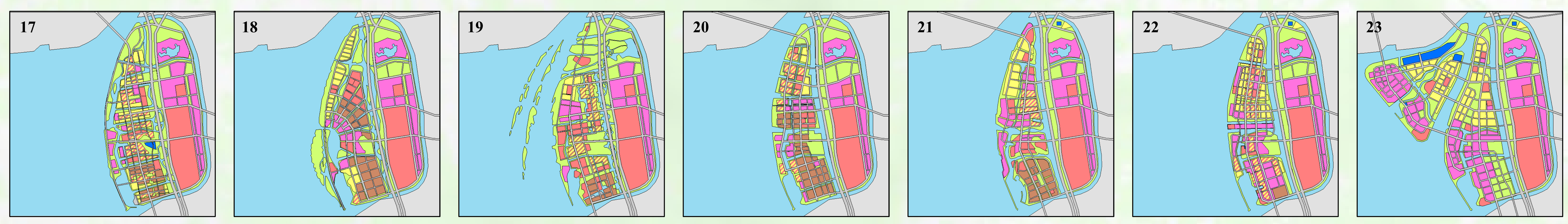
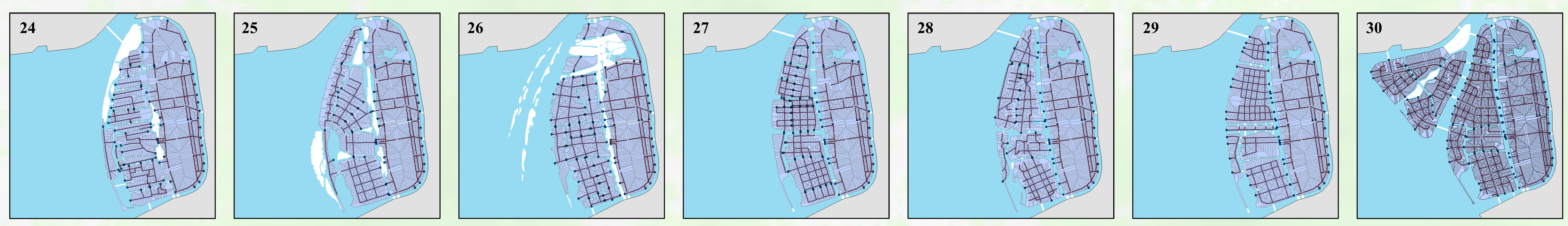


Fig 24-30
Gray infrastructure
Water
Industrial
Green Space
Outlet
Manhole



IV. Result

• TOPSIS – Multi Criteria decision analysis

Using TOPSIS to calculate the score (best distance) based on 6 criteria from scenario simulation, design model – 3 get the best score, design model -1 -2 & -4 get better score.
It means that Nature-based Solution has best performance and ecological resilience has better performance.

	design model-1	design model-2	design model-3	design model-4	design model-5	design model-6	design model-7
Scenario1	0.073398	0.083686	0.074335	0.080277	0.077671	0.114505	0.088329
Scenario2	0.04504	0.037414	0.028391	0.046688	0.056058	0.106622	0.051531
Scenario3	0.076086	0.091234	0.079859	0.082779	0.080051	0.115968	0.092434
Average scores	0.064841	0.070778	0.060862	0.069915	0.07126	0.112365	0.077431
rank	2	4	1	3	5	7	6

• Urban Inundation Model – Spatial & temporal scale of flood area and Water Exchange among water subsystem.

Due to high altitude (high cost), design model-4 gets the best performance during 3 scenarios. While in lower altitude, design model-2's green infrastructure retains more exceed water than design model-3's, protects more roads and development lands. However, design model-1 shows urban greening perform better than outer's during rainfall.

Scenario 1
Fig 31-37
Spatial scale
Green Land Road
0.02
0.05
0.10
0.15
0.20
0.30

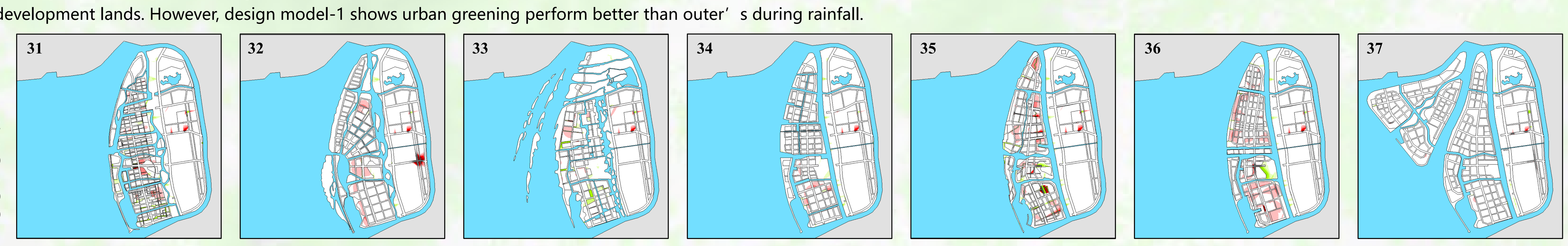


Fig 38-44
Temporal scale
Land
Road
Urban Green Space
Outer Green Space

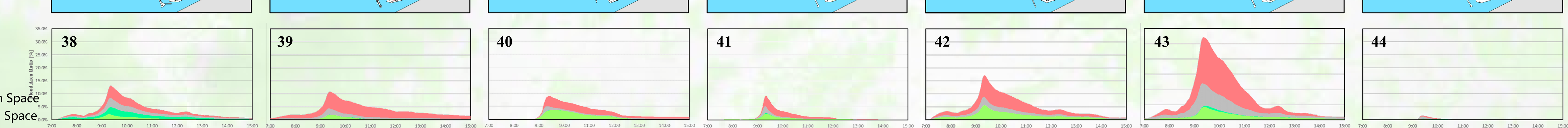
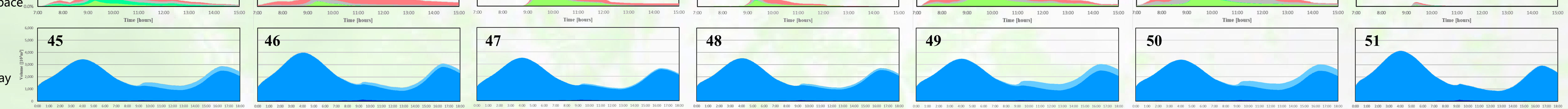


Fig 45-51
Water Exchange
Urban Surface
Urban Waterway
Pipe Network



Scenario 2
Fig 52-58
Spatial scale
Green Land Road
0.02
0.05
0.10
0.15
0.20
0.30

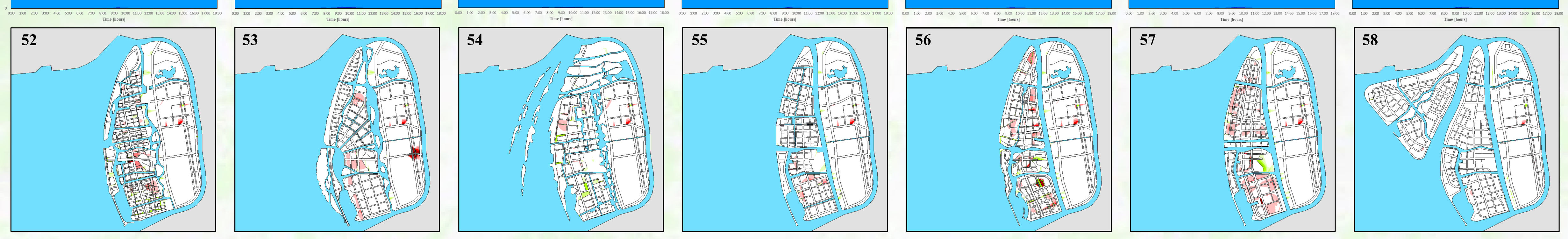


Fig 59-65
Temporal scale
Land
Road
Urban Green Space
Outer Green Space

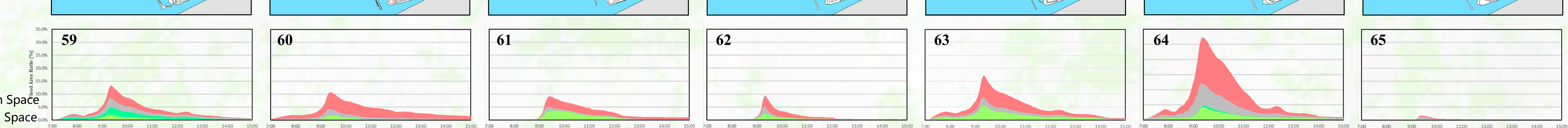
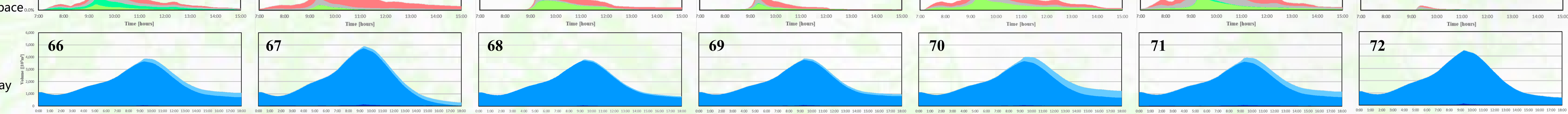


Fig 66-72
Water Exchange
Urban Surface
Urban Waterway
Pipe Network



Scenario 3
Fig 73-79
Spatial scale
Green Land Road
0.02
0.05
0.10
0.15
0.20
0.30

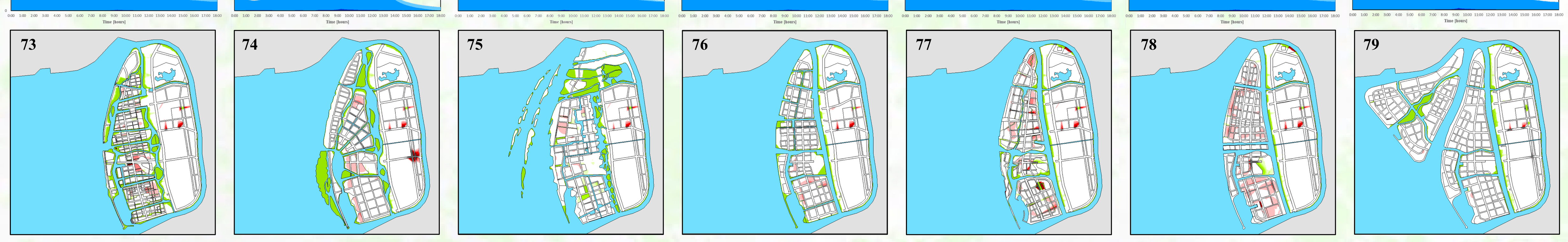


Fig 80-86
Temporal scale
Land
Road
Urban Green Space
Outer Green Space

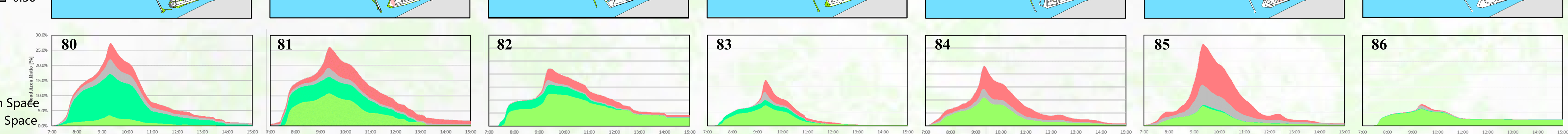
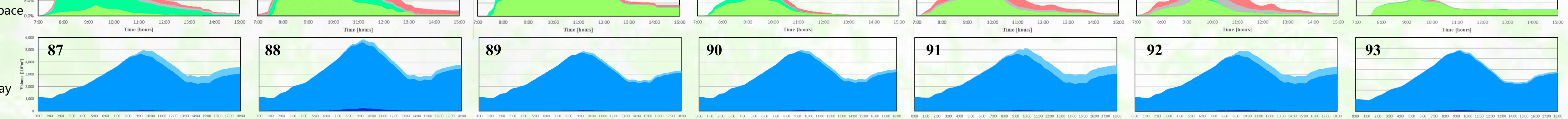


Fig 87-93
Water Exchange
Urban Surface
Urban Waterway
Pipe Network



V. Conclusion

Using **multidisciplinary knowledge** via TOPSIS to help policy makers identify the optimal resilience urban design model.

Scenario simulation of Green-Blue-Gray infrastructure can help urban planners understand the pros and cons in various urban design model concepts

1. **Traditional reclamation design model** with high altitude is high-cost, human-made, time-consuming, and low-risk.
2. **Engineering resilience design model** with middle altitude is high-risk while facing extremely rainfall.
3. **Nature-based solution design model** with lowest altitude is low-cost, nature-made, and low-risk, using surrounding green space to retain exceed water.
4. **Ecological resilience design model** with lower altitude low-risk, using dike system and river green space to retain exceed water.

VI. Future work

Transportation model

- Integrate transportation model into urban inundation model to evaluate the impact of submerge road.
- Use large-scale agent-based dynamic transportation modelling to simulate the variation of urban inundation.

Control single variable

Computational Efficiency

VII. Acknowledgement

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