中国水利水电科学研究院

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Urban pluvial flood modelling

application study in Shenzhen

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Outline

Motivation

■ Consensus achieved

- ✓ With the increase in frequency of flood events induced by intense rainfalls in urban areas, people living in those areas are exposed to high risk levels of pluvial flooding.
- ✓ The numerical model plays more important roles in urban flood risk management.
- ✓ The demand for building a **Pluvial Flood Model** in an urban area is rising.

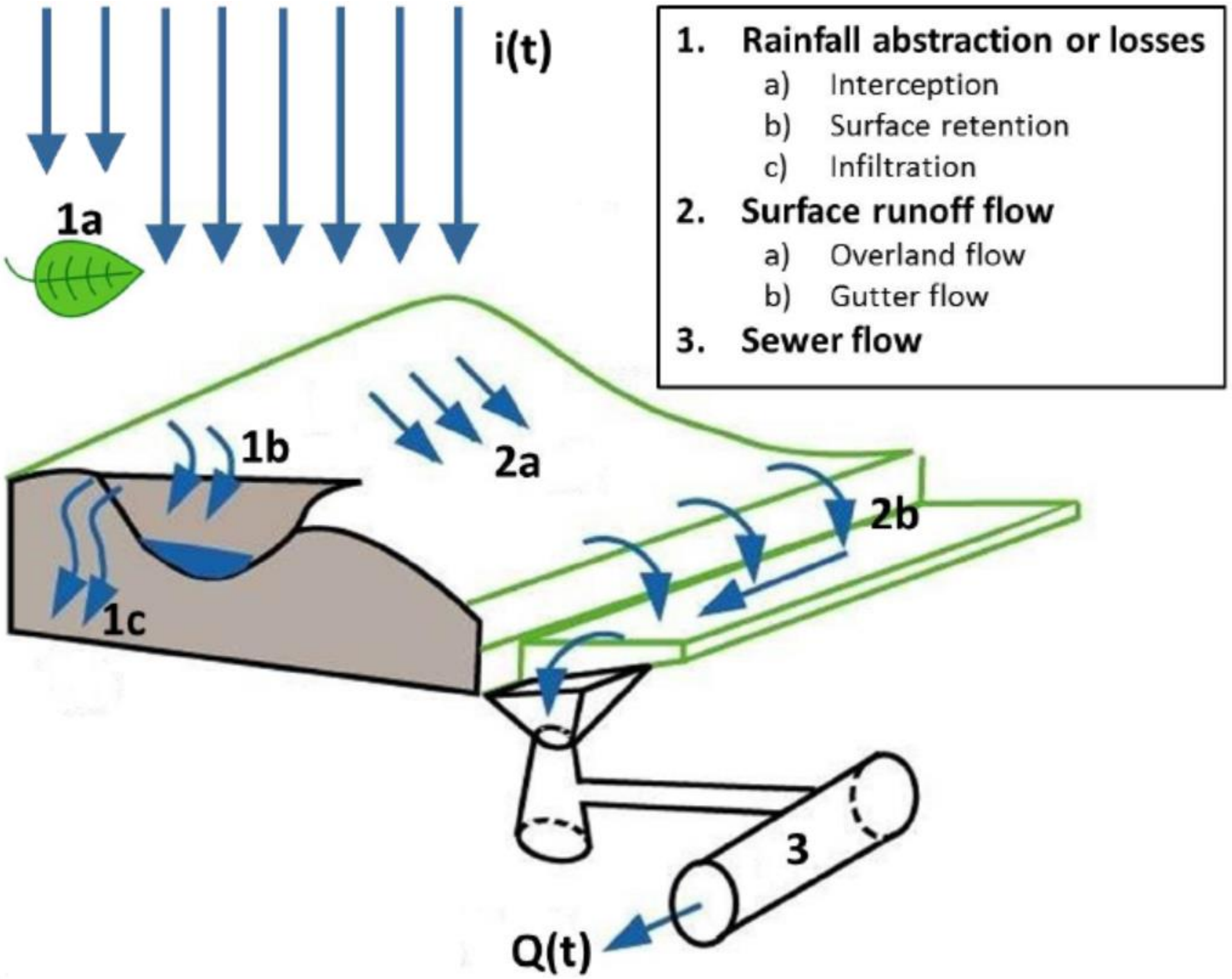
Introduction of urban pluvial flood models

- A holistic urban pluvial flood model generally consists of 3 sub-models:
  - runoff generation
  - surface runoff flow
  - sewer flow

  For each sub-model, there exist a lot of approaches:

  physically-based
  conceptual
  empirical
  data-driven

- Review of the development of urban pluvial flood models (Ref. Susana Ochoa-Rodriguez, urban pluvial flood modelling current theory and practice,2015)



Processes that take place once rainfall falls over an urban area

Introduction of urban pluvial flood models

■ Surface Runoff flow modelling

✓ Hydrological method (sub-catchment based)

~robust and less time-consuming.

~oversimplified, only offers runoff hydrograph at the outlet

✓ Hydrodynamic method (grid based)

~offers more detailed flow information (flood extent and depth)

~highly computationally demanding and time consuming

- 1D/2D hybrid model, in which the 1D model is used to simulate the flow in the river (being of **preferential direction**)

1. **Rainfall abstraction or losses**
   a) Interception
   b) Surface retention
   c) Infiltration
2. **Surface runoff flow**
   a) Overland flow
   b) Gutter flow
3. **Sewer flow**

Since each way has advantages and disadvantages, the selection of an 'appropriate' model depends on the characteristics of the area and purpose of the modelling.

Our models

- **Study area:**

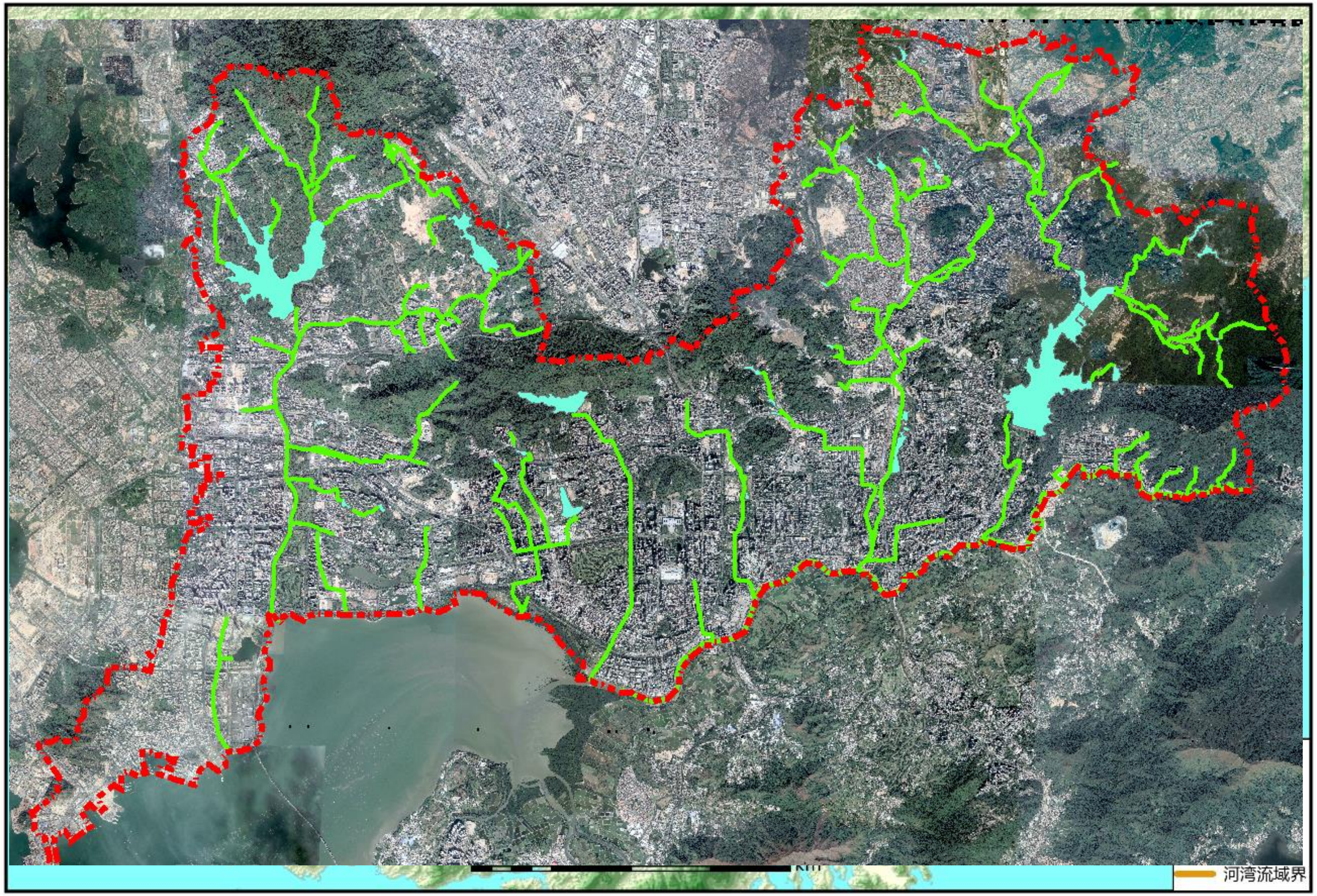
  ~300km^2

- **Land type:**

  Downtown area+
  non-build-up area

- **Aim:**

  To build a model to describe the water behavior once the rainfall falls over the land under certain rainfall conditions. (the coarse model; the refined model)



Our models

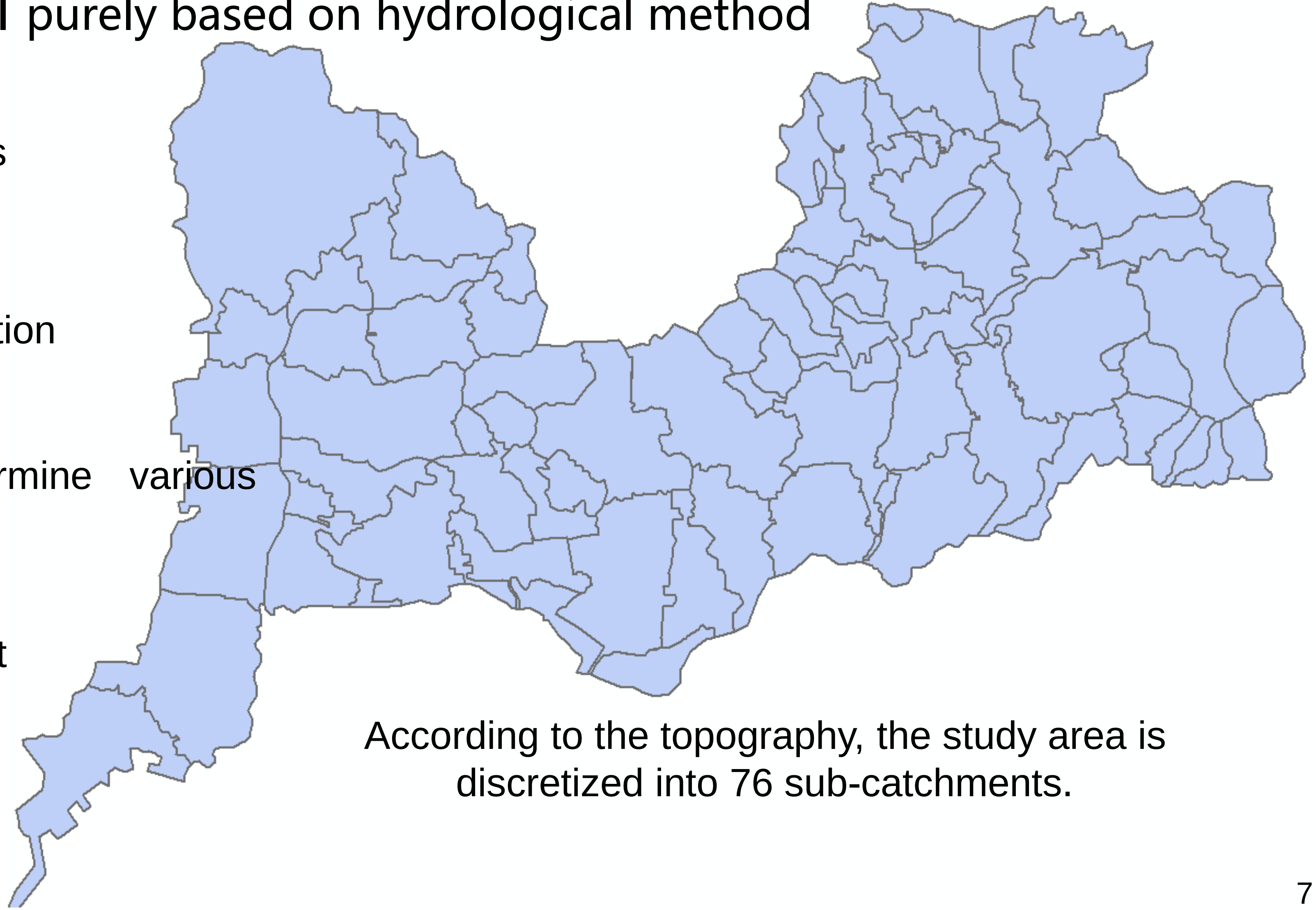
■ The coarse model

1. Rainfall-runoff sub-model purely based on hydrological method

- Objects:
  land, reservoirs, minor rivers

- Processes:
  runoff generation
  overland runoff concentration
- Inputs:
  rainfall data
  land use data (to determine various parameters)

- Outputs:
  flow hydrograph at the outlet
  reservoirs' information



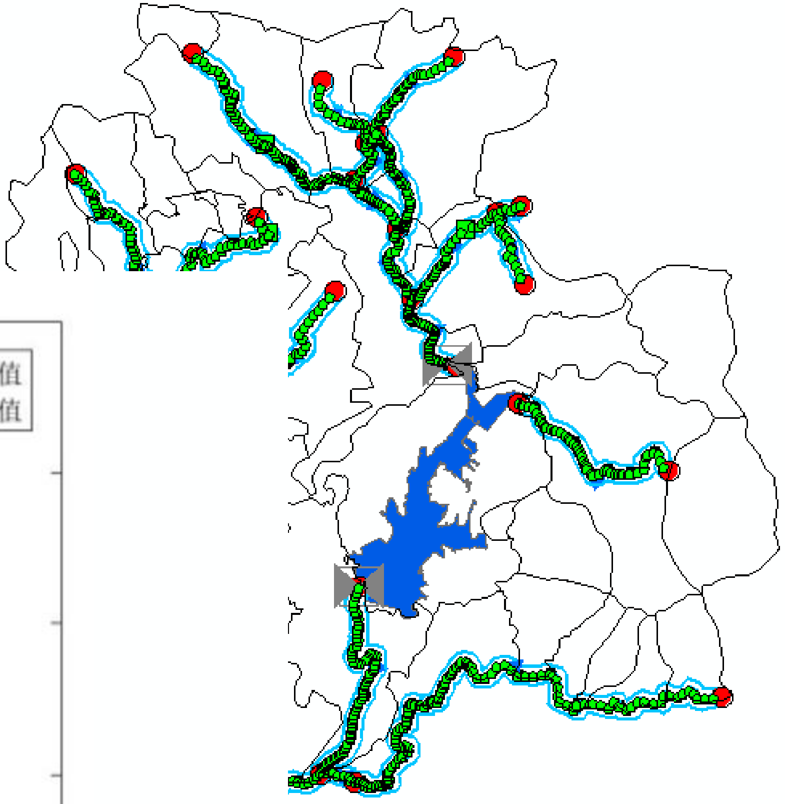
According to the topography, the study area is discretized into 76 sub-catchments.

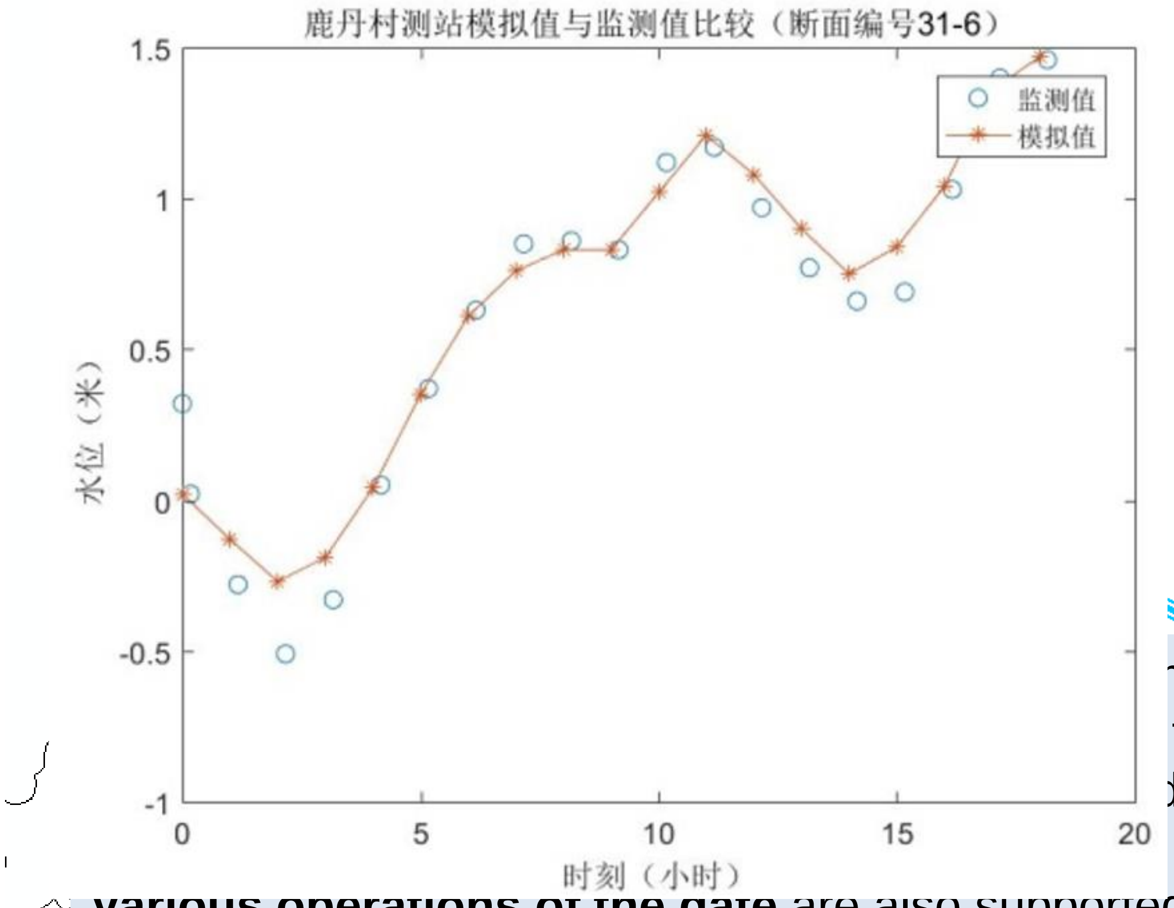
Our models

■ The coarse model

2. River network sub-model (1D)

hydrodynamic; solve shallow water equations





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inflow.
various operations of the gate are also supported.

Our models

■ The coarse model

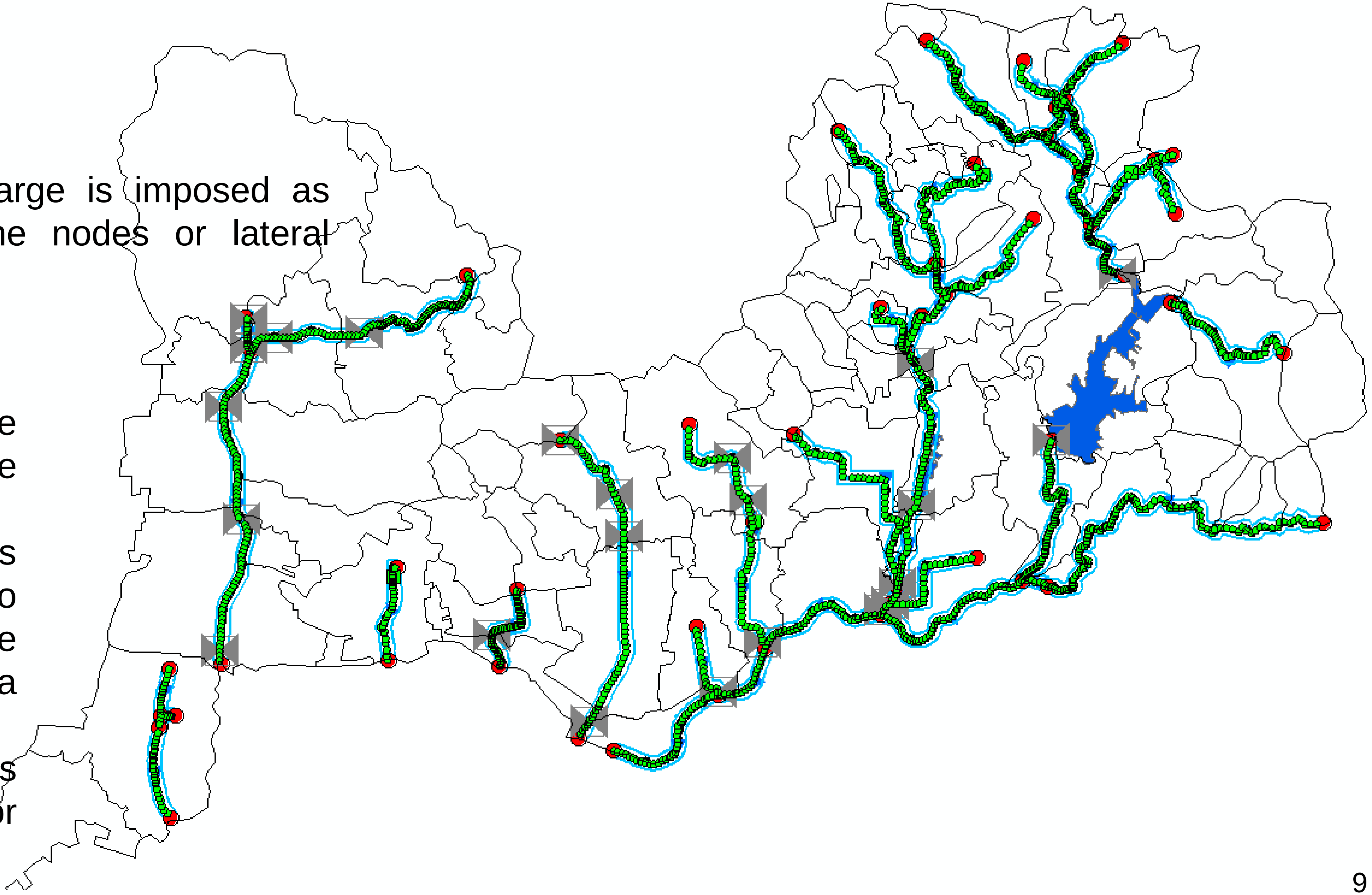
✓ **Coupling**:

one-way;

the outflow discharge is imposed as boundary conditions at the nodes or lateral inflows at the sections.

✓ **Advantages**:

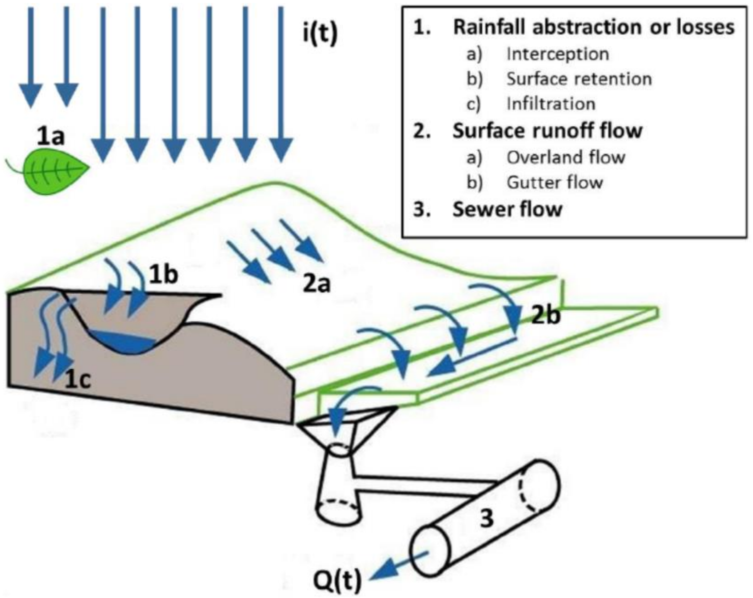
- A tool can evaluate the flood risk related to the rivers and reservoirs.
- It supports various operations of the gate, so it can help manage the reservoirs or gates in a storm event.
- The computation cost is small, so it's suitable for real-time application.



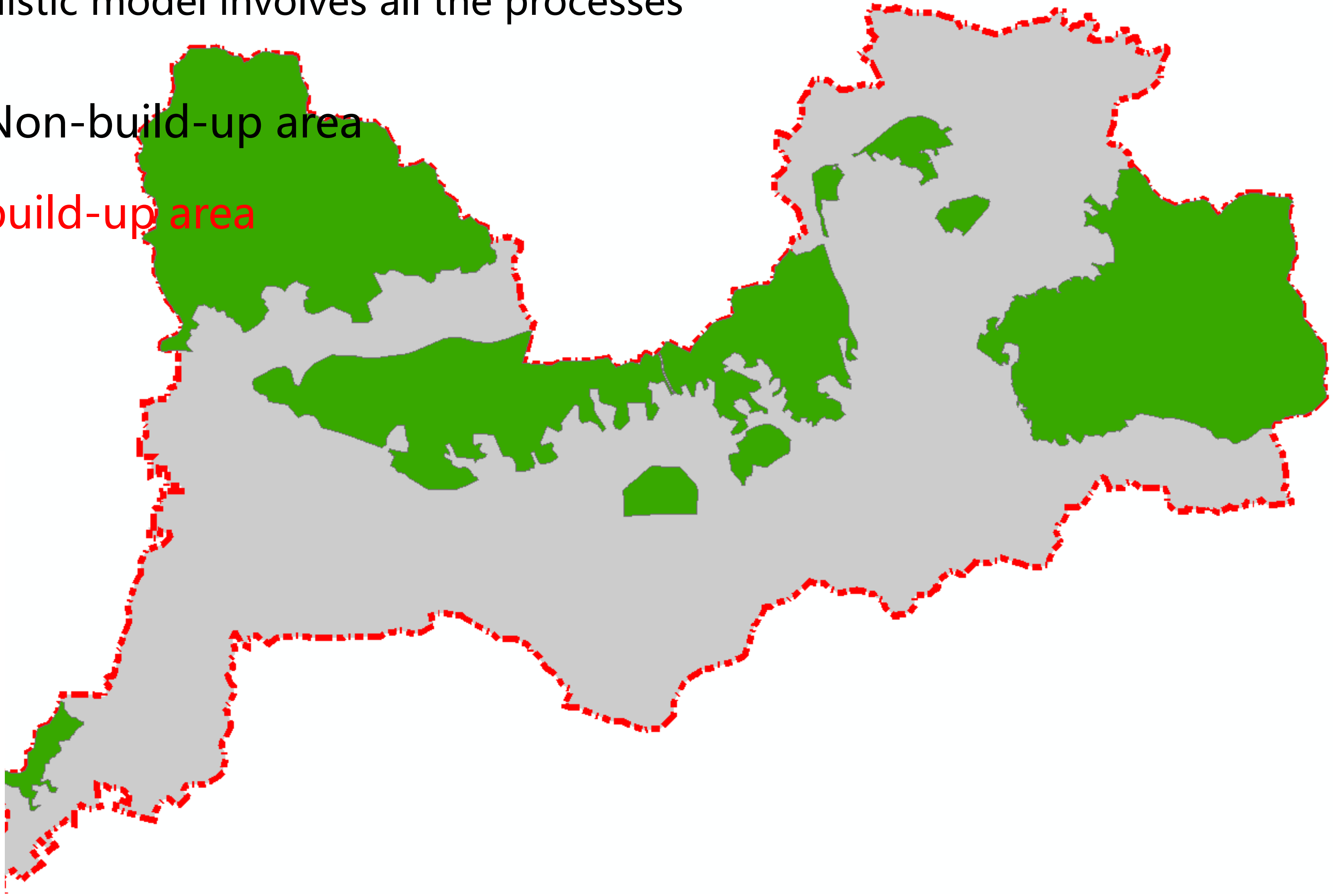
Our models

■ **The refined model** a holistic model involves all the processes

1. Overland flow model for Non-build-up area
2. Overland flow model for build-up area
3. River network model (1D)
4. Pipe network model(1D)



Processes of the water flow after the rainfall hits on the ground



Our models

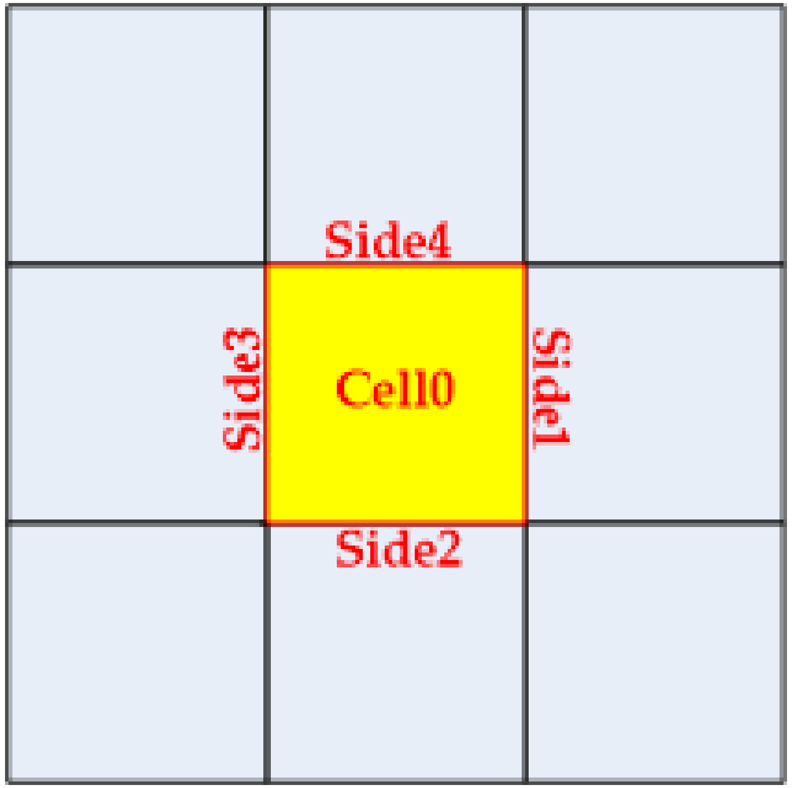
■ The refined model

Overland flow model for build-up area ⟷ **2D hydrodynamic model (with ~300 million grids)**

✓ Processes:
- runoff generation
- runoff concentration flow

✓ Difference with the coarse model:
- based on each grid
- runoff concentration is described by solving 2D shallow water equations

✓ In addition to being able to offer more detailed information at any location, by coupling with the following pipe model, it can simulate the **runoff concentration** and **sewer flooding** simultaneously, while in the literature, a lot of research work treats them as two separate stages of runoff flow.



Sample mesh

Our models

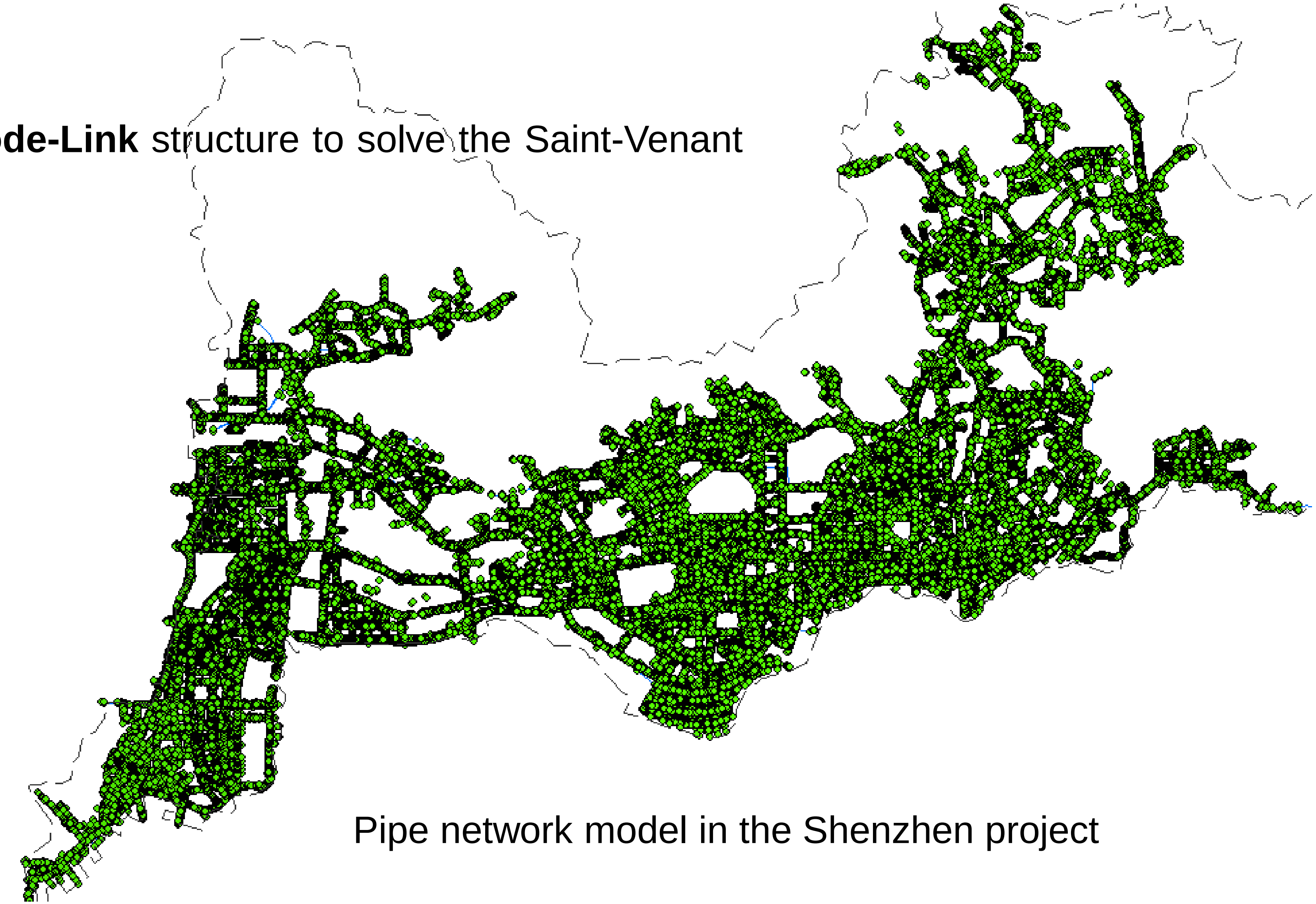
■ The refined model

✓ Pipe network model(1D)

- **SWMM-like** solver using **Node-Link** structure to solve the Saint-Venant equations

Nodes number: 128,125

Links number: 127,228



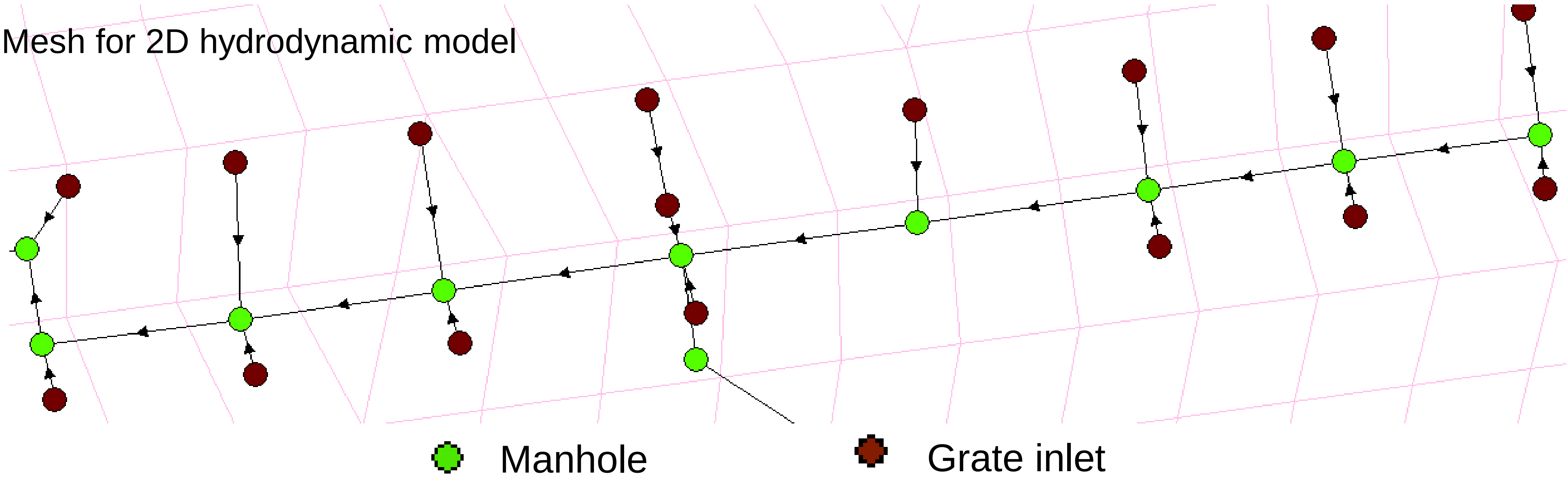
Pipe network model in the Shenzhen project

Our models

■ The refined model

✓ Pipe network model(1D)

- **SWMM-like** solver using **Node-Link** structure to solve the Saint-Venant equations



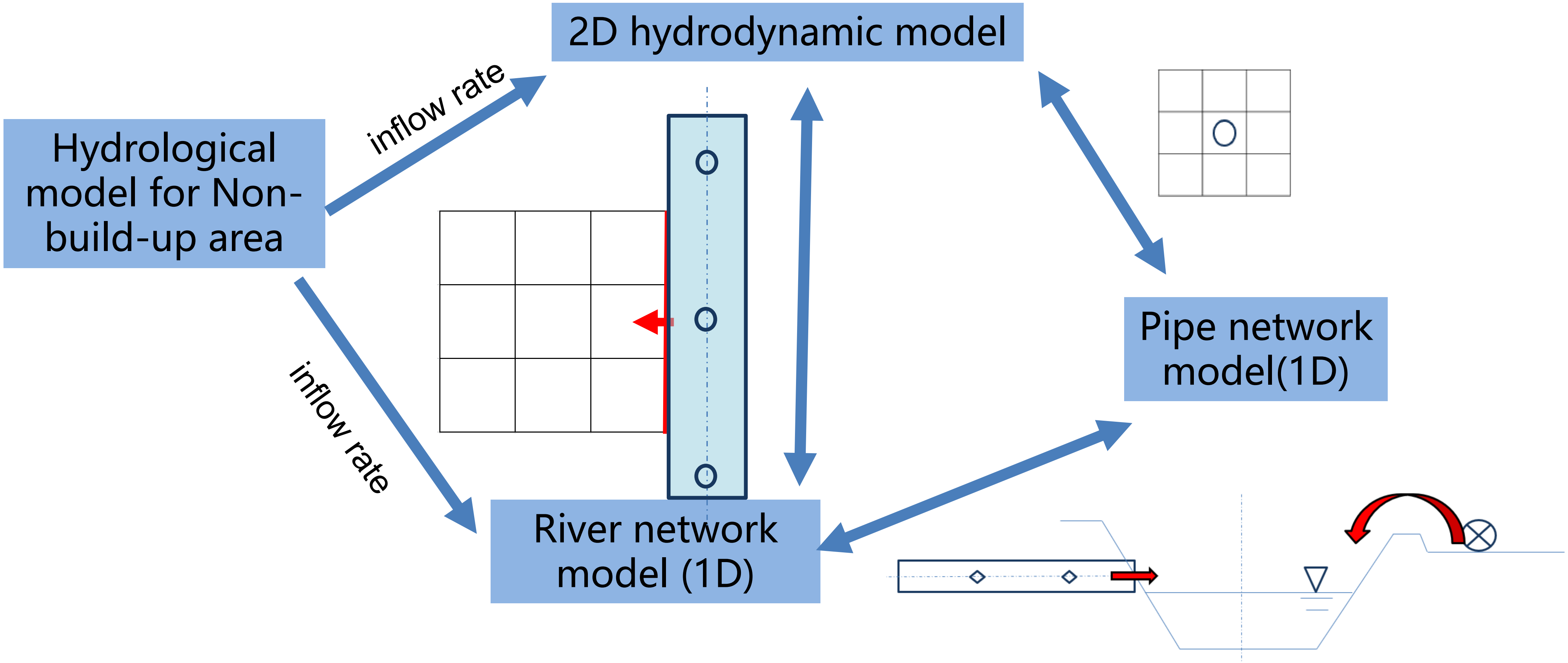
Locally magnified

The difference with SWMM: A new object type, i.e., grate inlet, is added. At the **manhole**, it only allows surcharged water to flow from the pipe to the ground, while at the **grate inlet**, the water exchange is two-way, which is more near to the real situations.

Our models

■ The refined model

✓ Interaction between each two sub-models



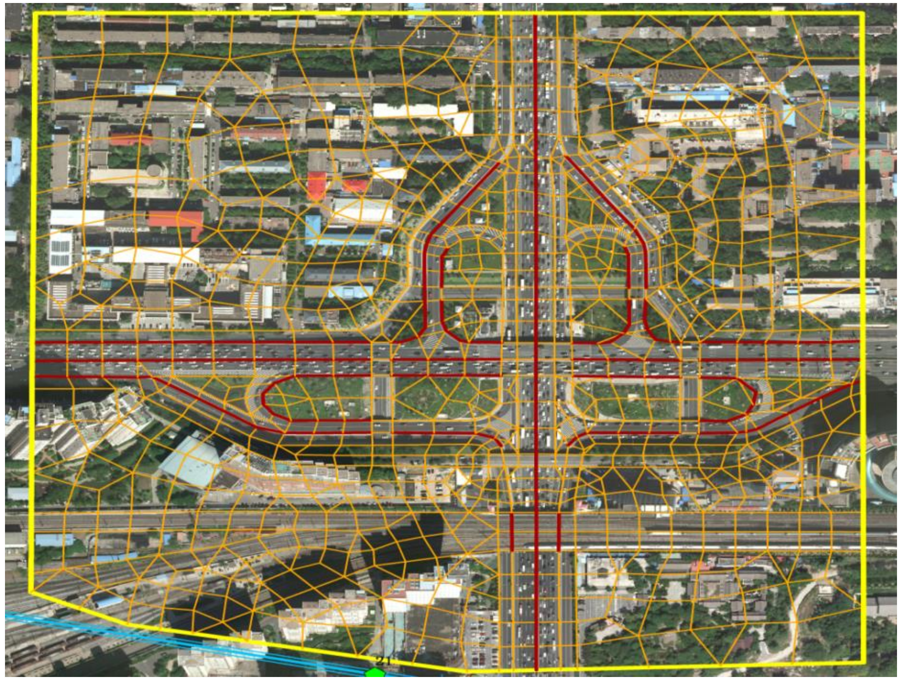
Our models

■ The refined model Ability to describe the flow details at the **most concerned local areas**

Road: pathway to transport water

Example to reflect the fact that water flowing on the road has preferential direction

- Draw control lines along the road sides (over the whole study area)
- Special sides (e.g., dyke-like side to account for blocking effect)



Body-fitted Mesh

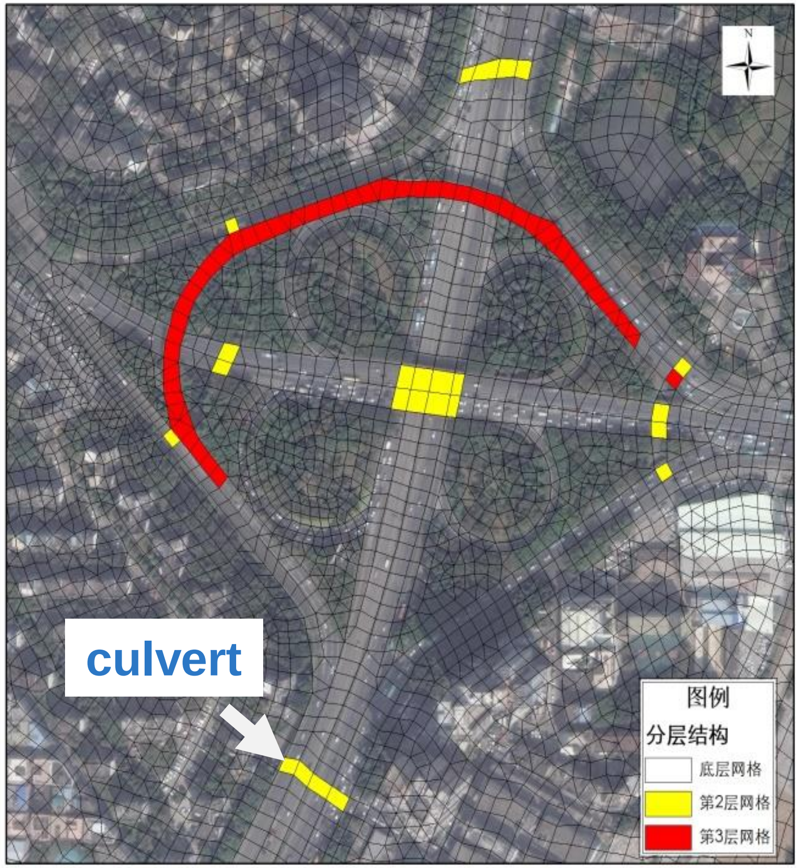
Water starts to pond at the lower part of the road

Without using the control lines and special sides, if the mesh is coarse and the elevation is not well assigned, the water may spread in any direction.

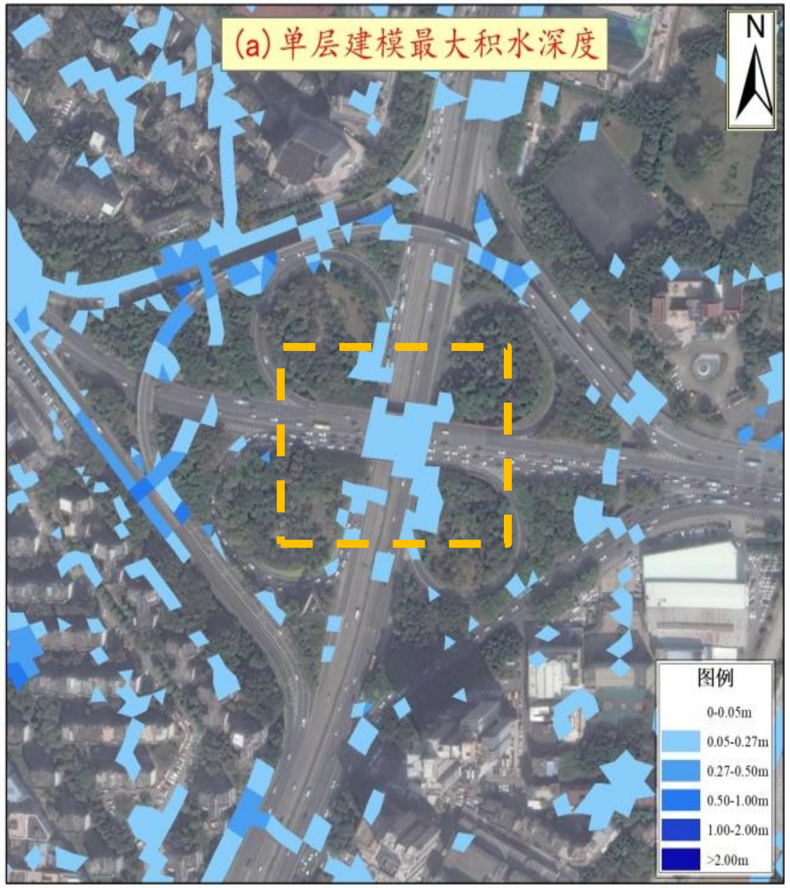
Our models

■ The refined model

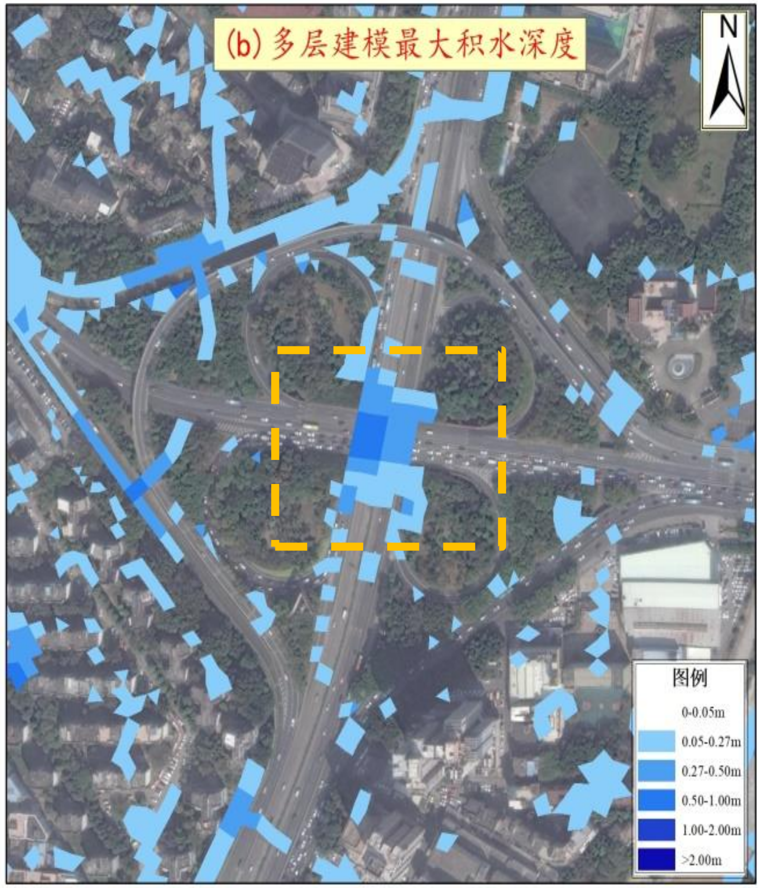
Overpass: a special part of the road, which is a vulnerable area in the storm event, its complex structure , especially in the vertical direction, makes it hard to describe the **concentration** process.



Multi-layer mesh



Largest water depth of single-layer model



Largest water depth of multi-layer model

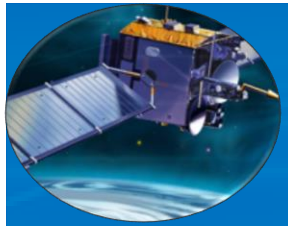
Summaries

- Two different pluvial flooding models in terms of the degree of simplification are built for Shenzhen project to meet different requirements.

- The coarse model can evaluate the flood risk related to the rivers and reservoirs; the short runtime makes it suitable for real-time application.

- The holistic refined model is less simplified on physics, so it can provide more detailed flow information, but it’s also more computationally demanding, even though some efforts have been made to achieve a balance between accuracy and computational demands, such as combining the 2D dynamic model with 1D river network model and hydrological runoff concentration model for non-build-up areas.

- In the coming future, these two models need to be further calibrated and verified; and the computation of the refined model needs to be accelerated, e.g., through GPU techniques.



Thank you for your attention!