Unit of Environmental Engineering

Automated Pipe-sizing of Storm Sewer or Combined Sewer Systems Based on Hydrodynamic Modelling

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1. Introduction

<u>Problem</u> **Flood protection-based sewer network design**

<u>Objectives</u> **Minimize cost, no flooding**

<u>Solutions</u>

No surcharging

- Dynamic programming
- Linear programming
- Nonlinear programming

With surcharging

- Evolutionary methods,
- e.g. GA, Particle swarm

Shortages of Evolutionary Methods

- Control parameters required

  To determine: trial-and-error

- High computational cost
- Inherently stochastic

  Different implementations → different solutions

2. Method

- No control parameters

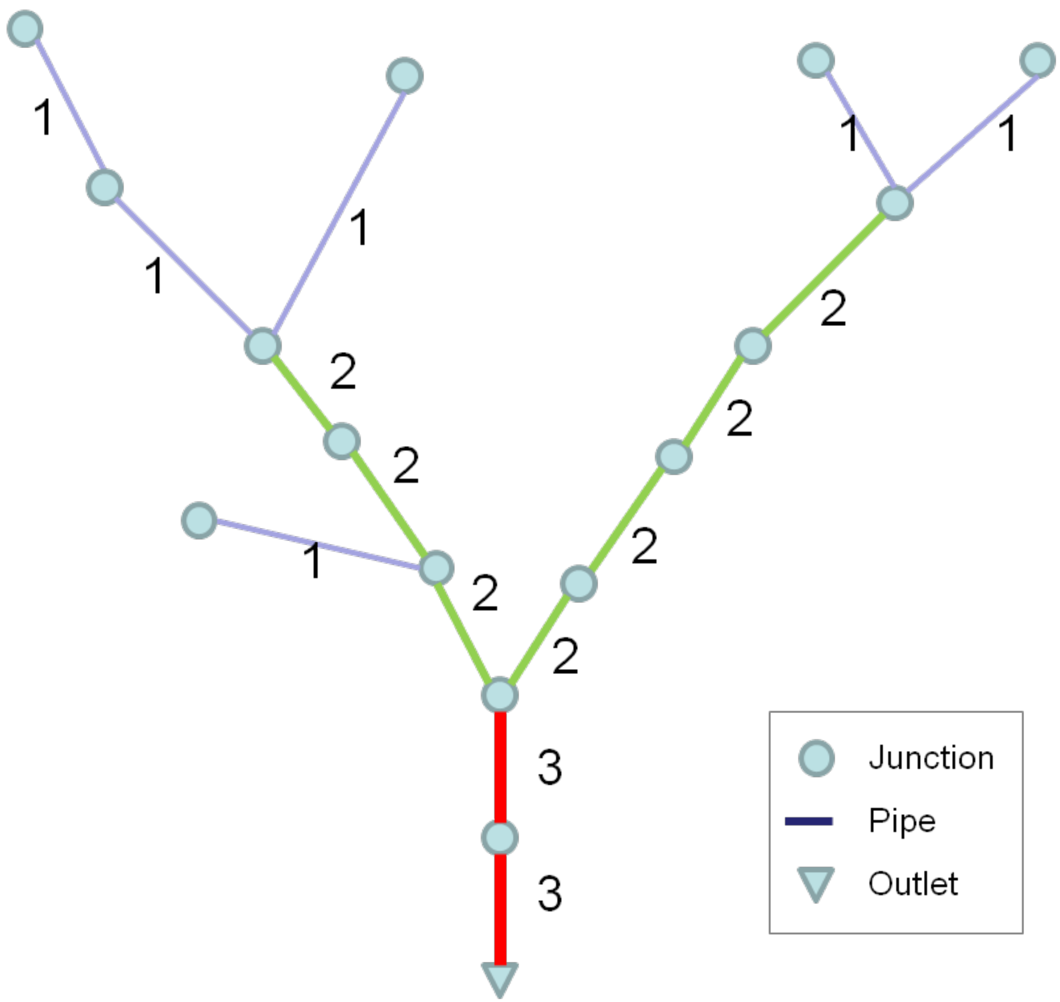
  No need of pre-runs

- Deterministic

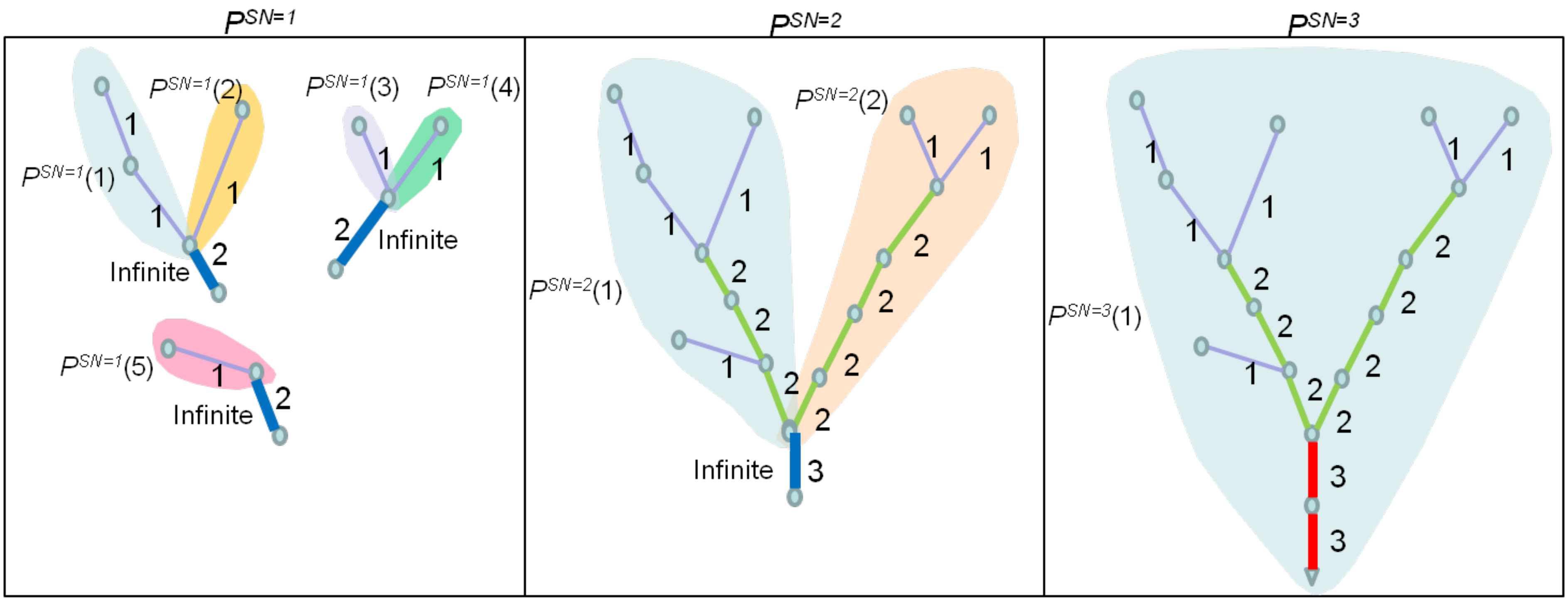
The Principle

Maximize the storage capacity of upstream pipes so that the sizes of downstream pipes can be minimized.

Step.1: "Sewer branch order" — *Strahler Numbers*



Step.2: Network Decomposition



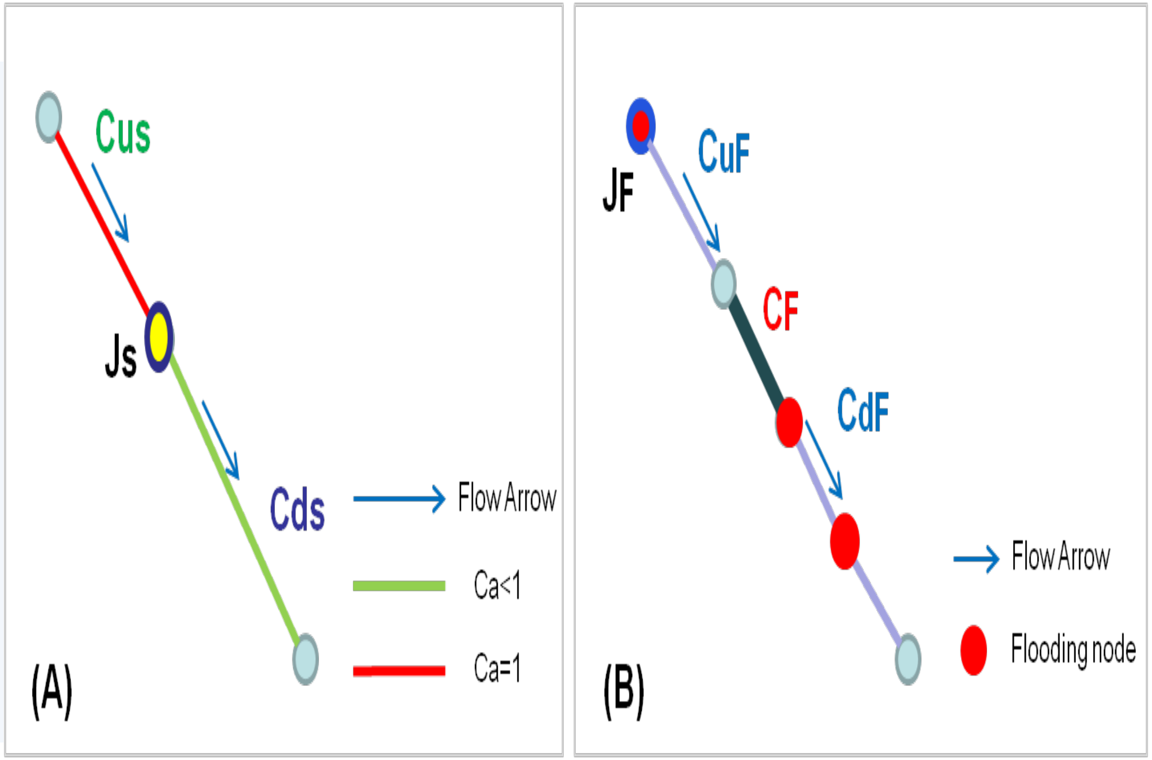
Step.3: Pipe Sizing

Generally:

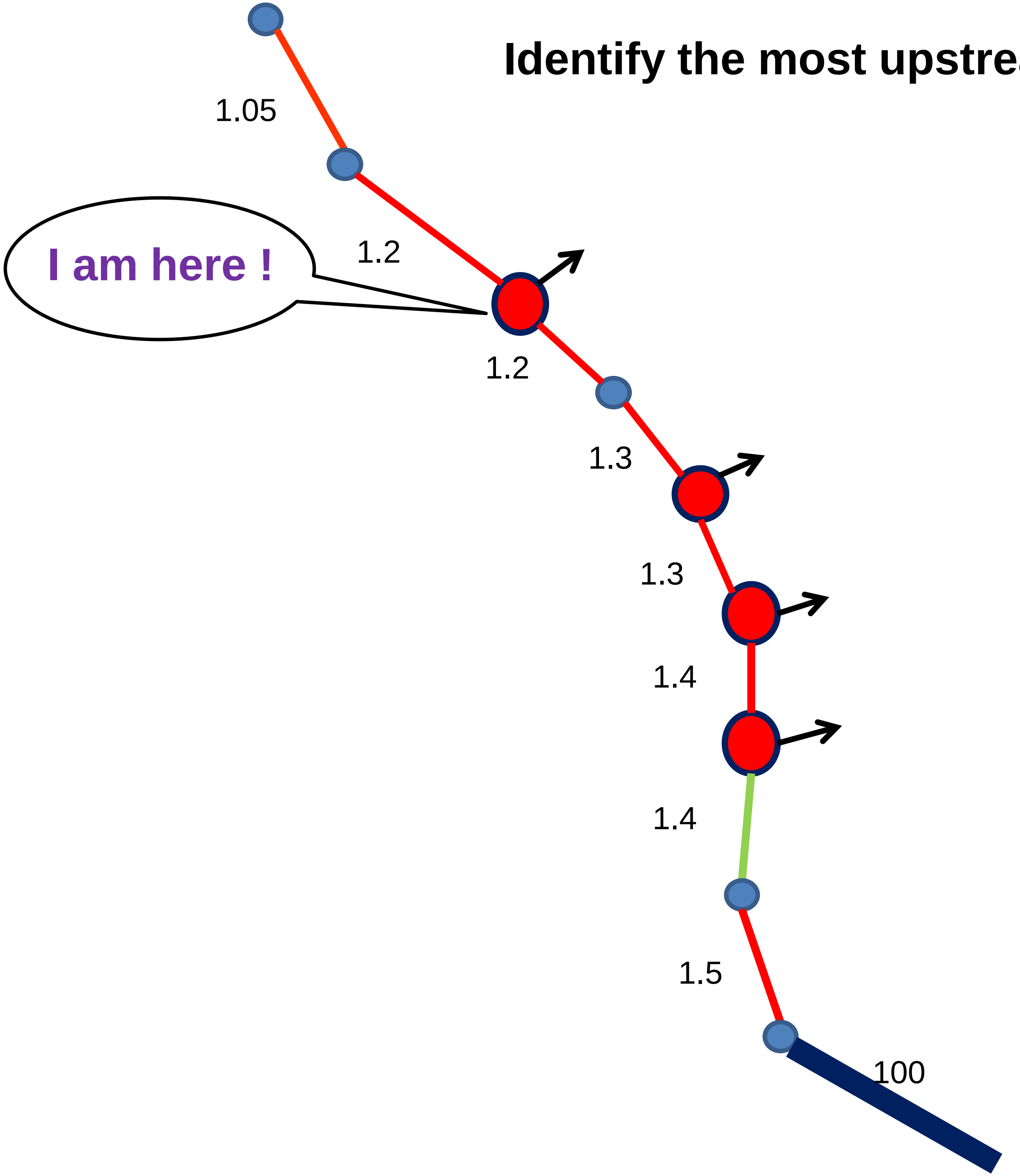
Optimize the capacity of each subsystem following the hierarchical structure of the studied network.

In details:

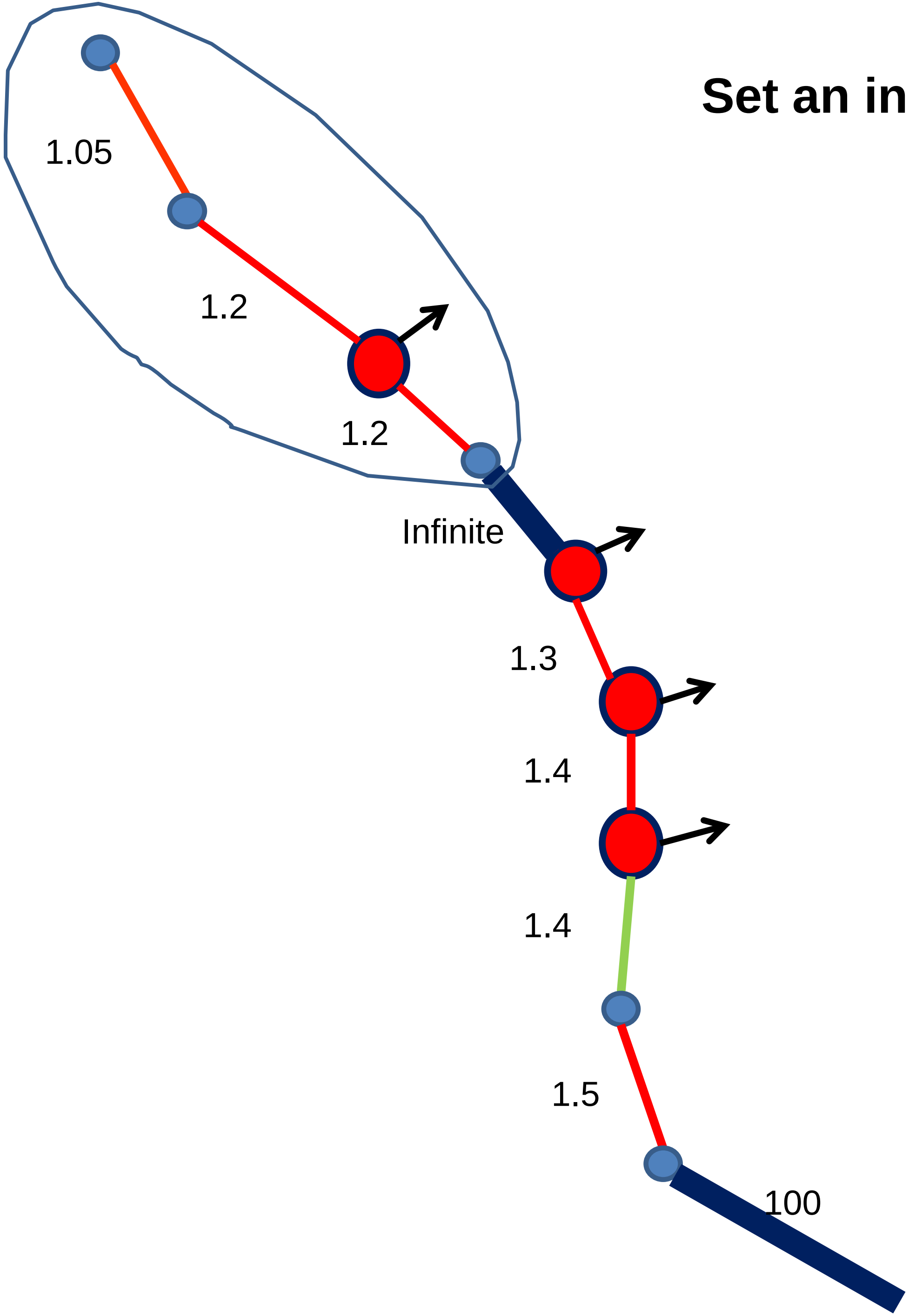
1) Identify the most upstream flooding node J_F;
2) Set C_F to be "Infinite pipe" ;
3) Locate **Js** node ;
4) Enlarge pipe **Cus** ;
5) Repeat step 3 to 4 till no floodings in pipes C_{uF};
6) Update C_F with C_{dF} , repeat Step 3 to 5;



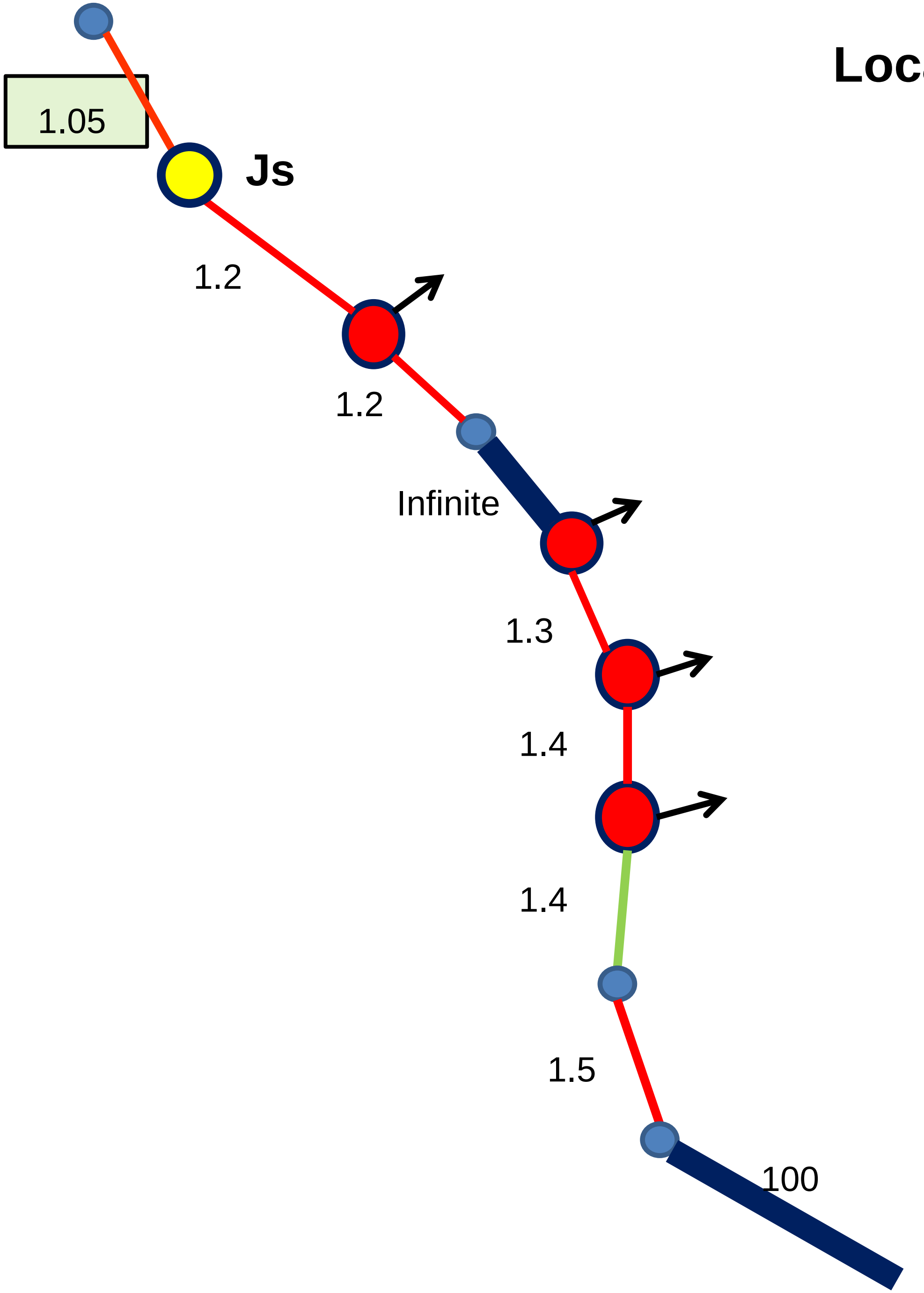
Identify the most upstream flooding node



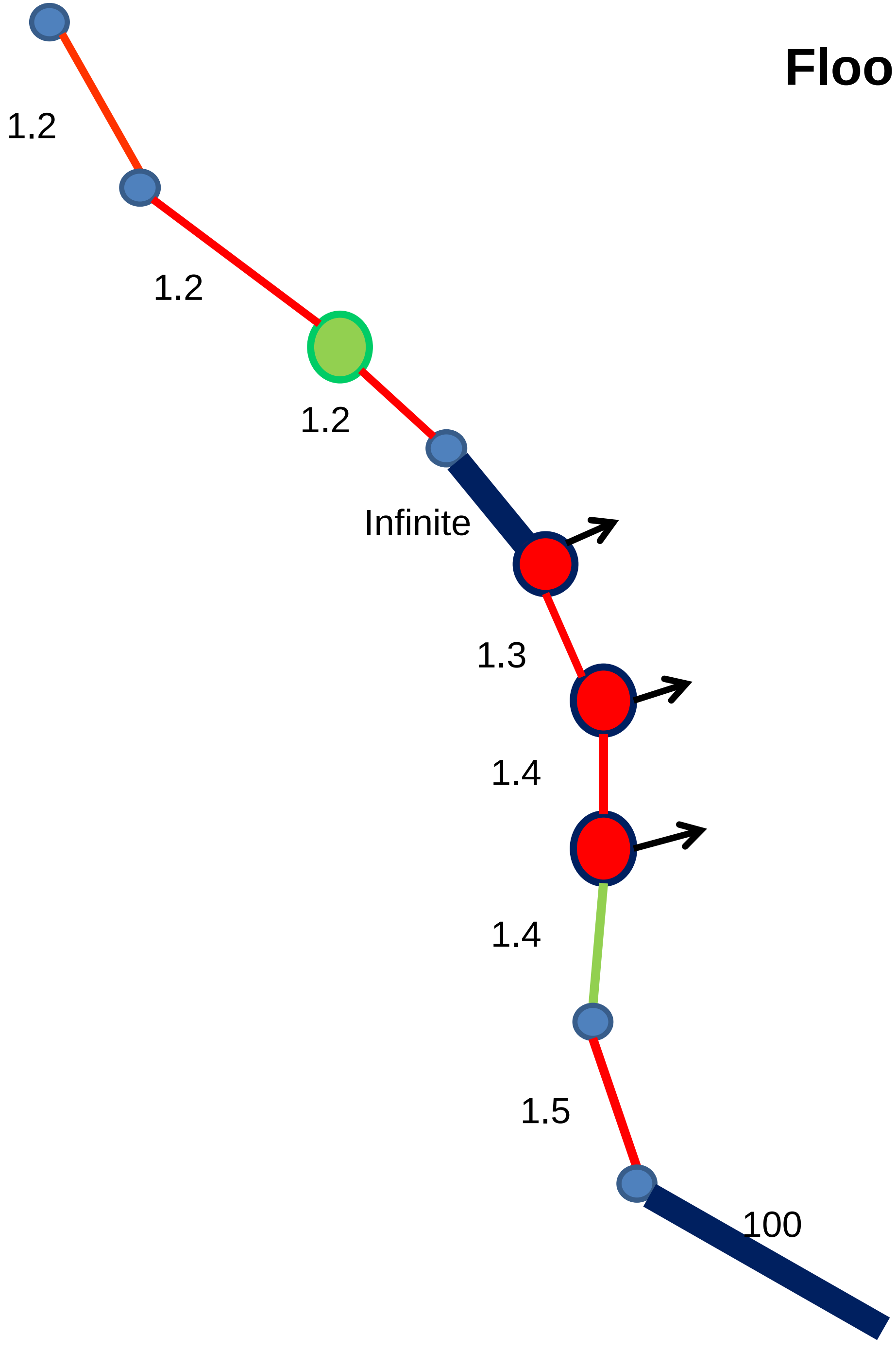
Set an inner “infinite pipe”



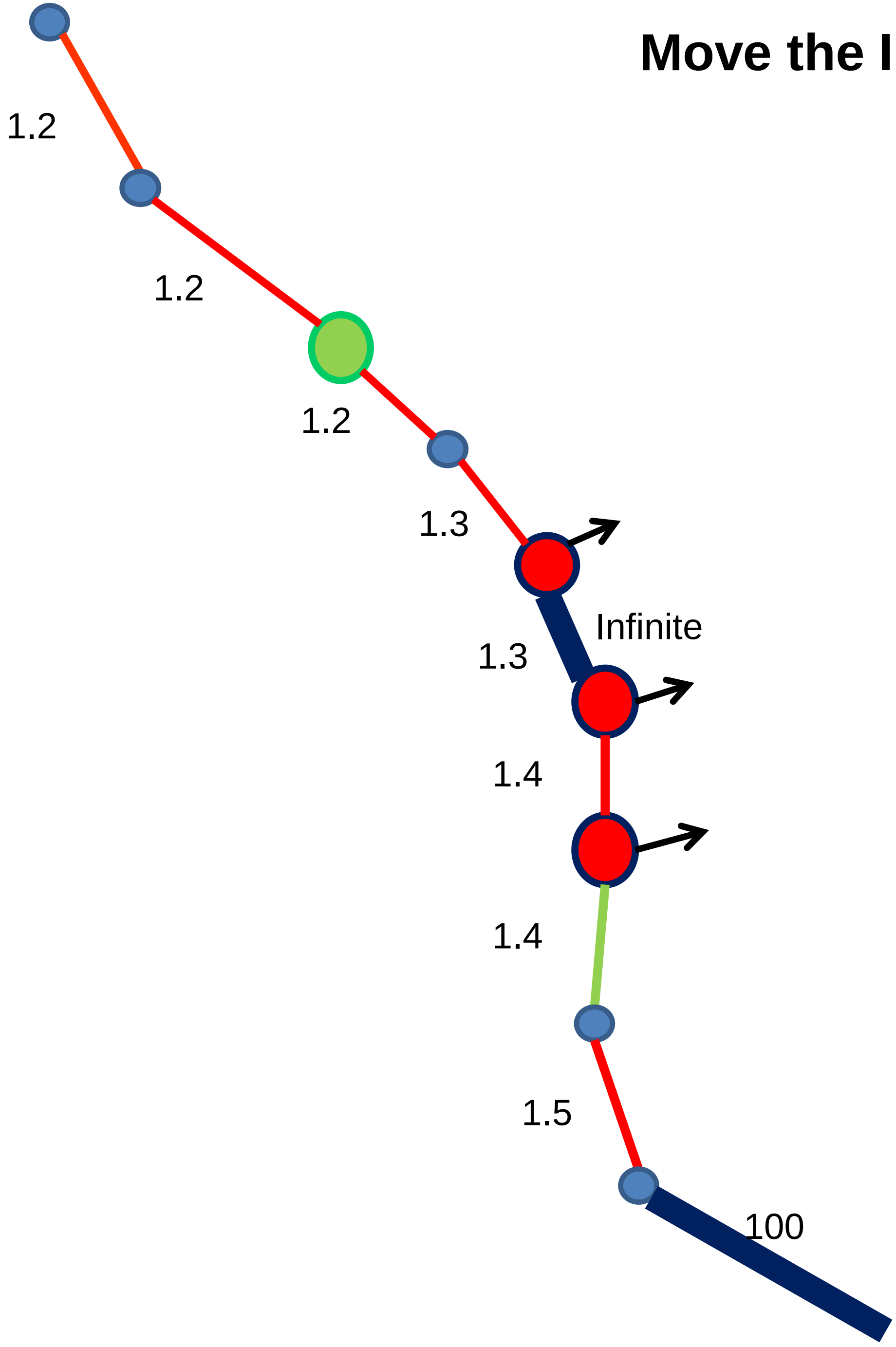
Locate the Js node

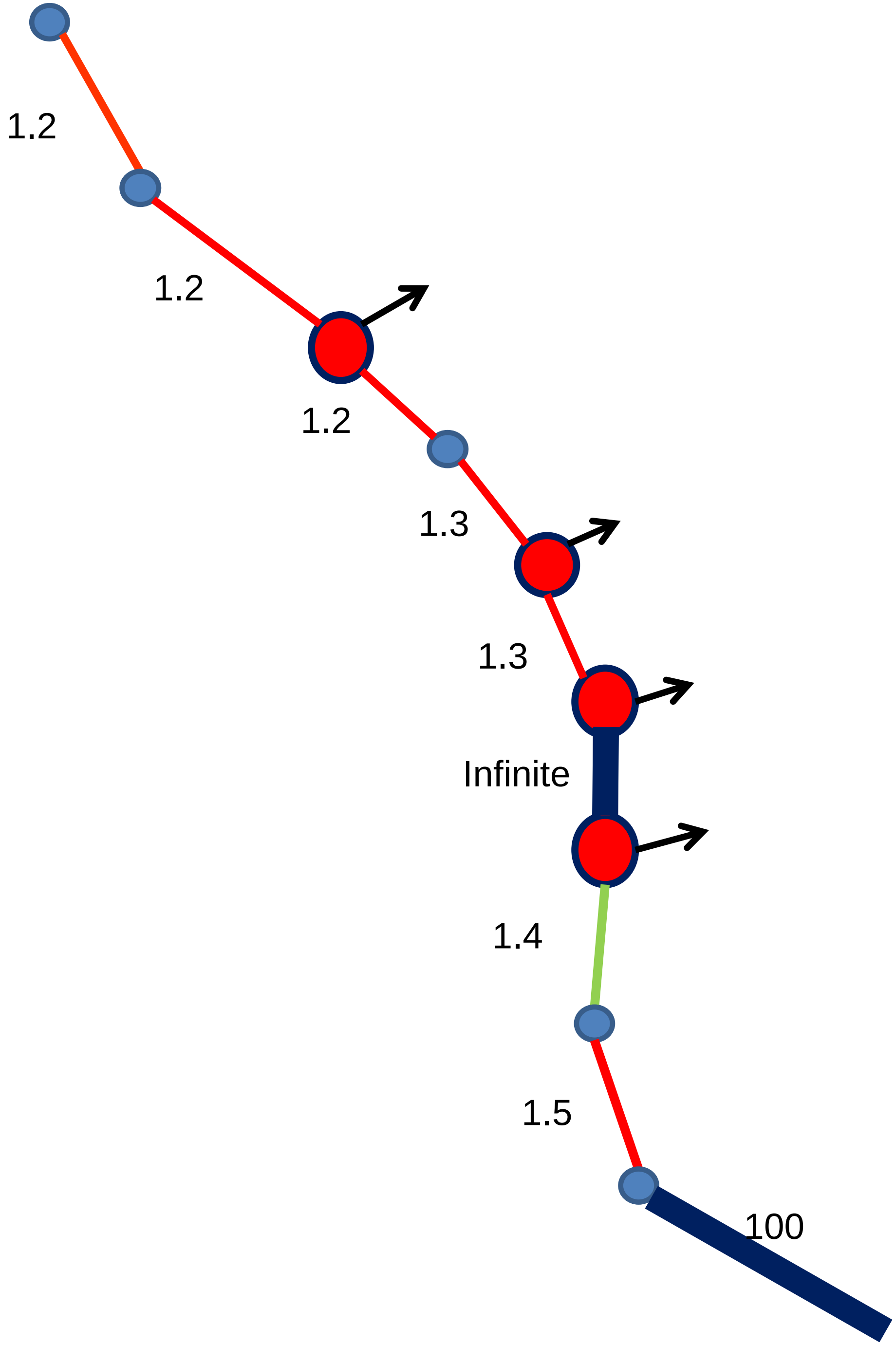


Floods accommodated



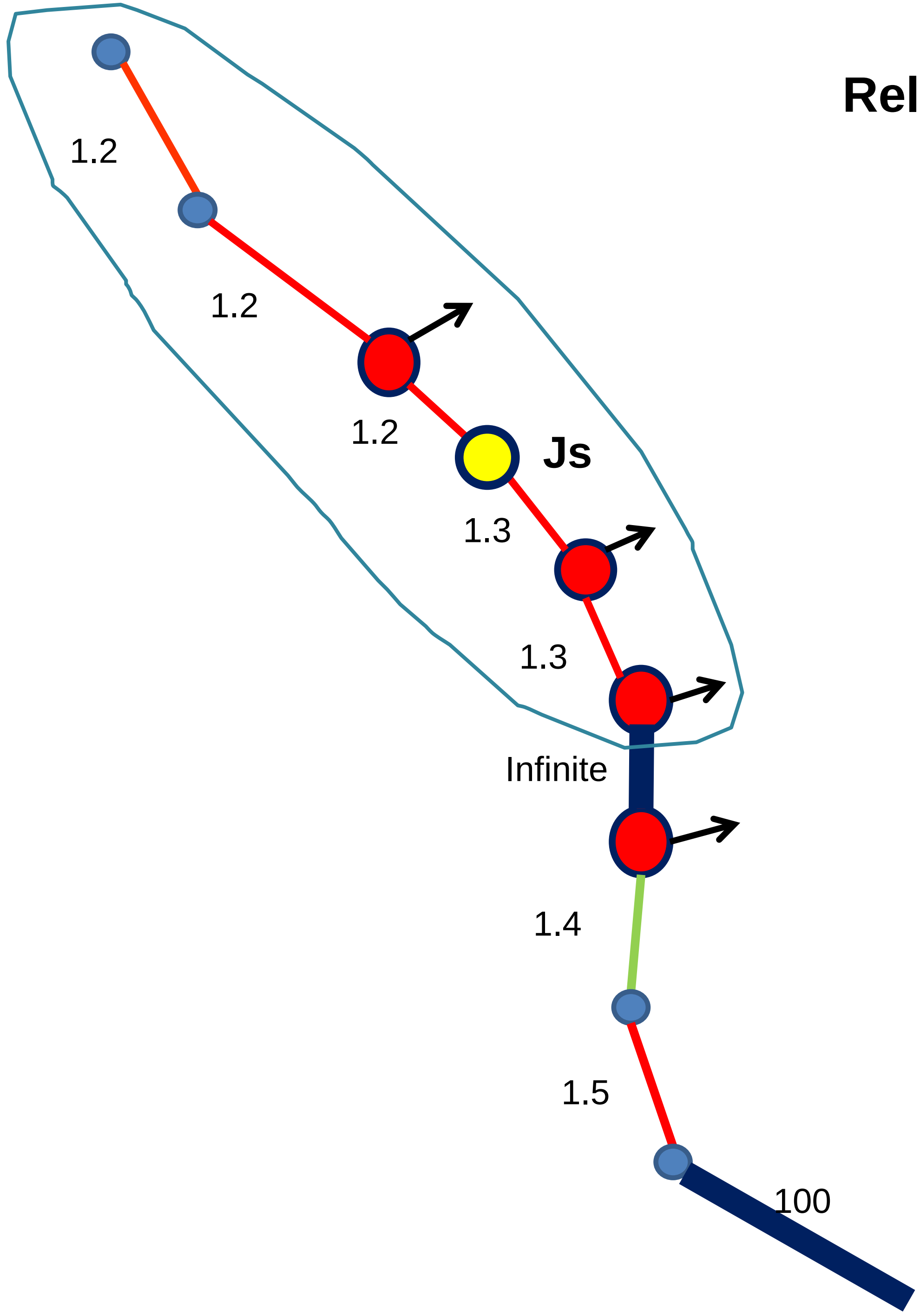
Move the Infinite downwards





1.2
1.2
1.2
1.3
1.3
Infinite
1.4
1.5
100

Relocate the Js node



3. Results and Discussions

Case Study:

Catchment Area: 175 (ha)

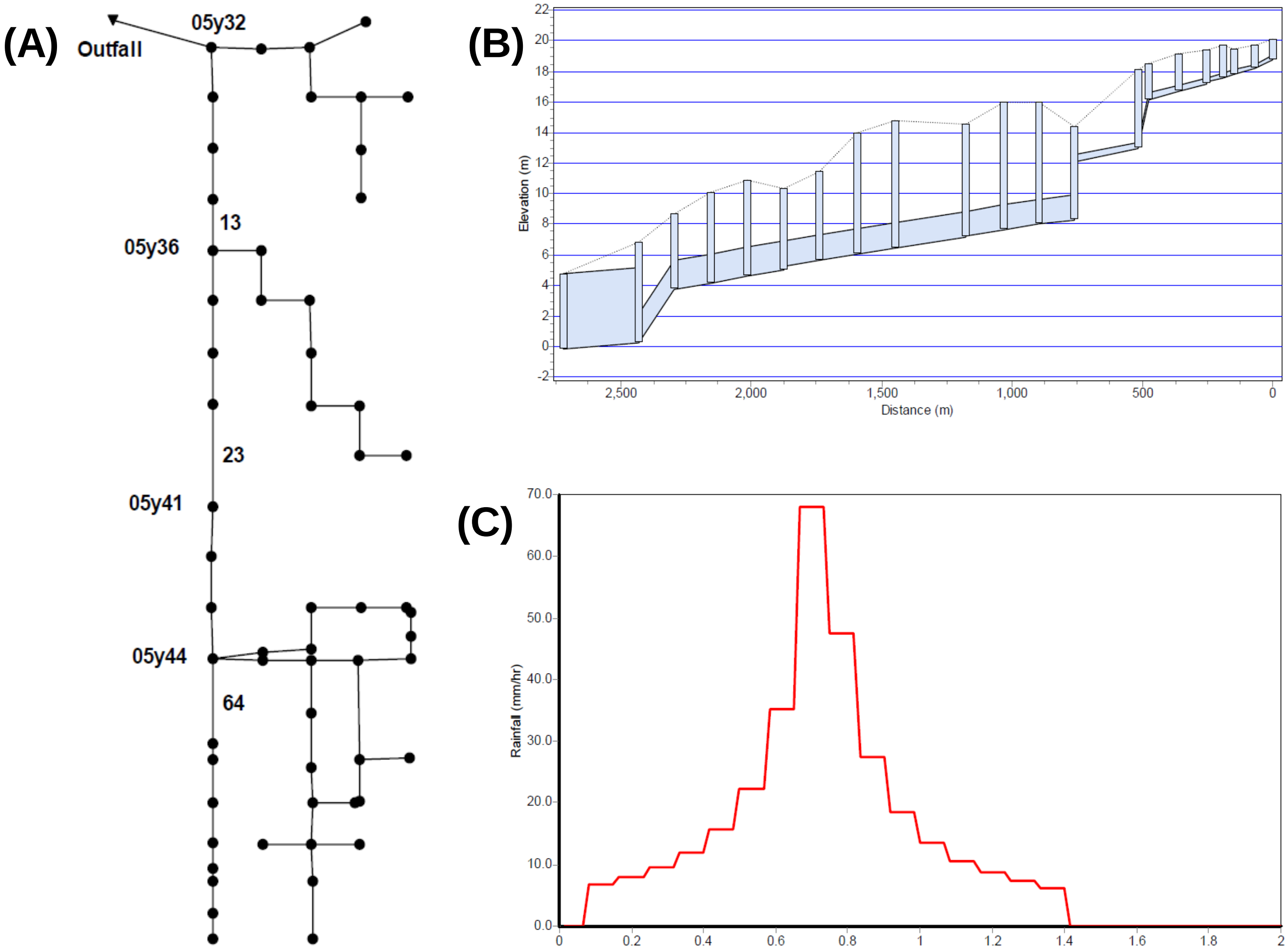
Subcatchments: 58

Terrain: Steep

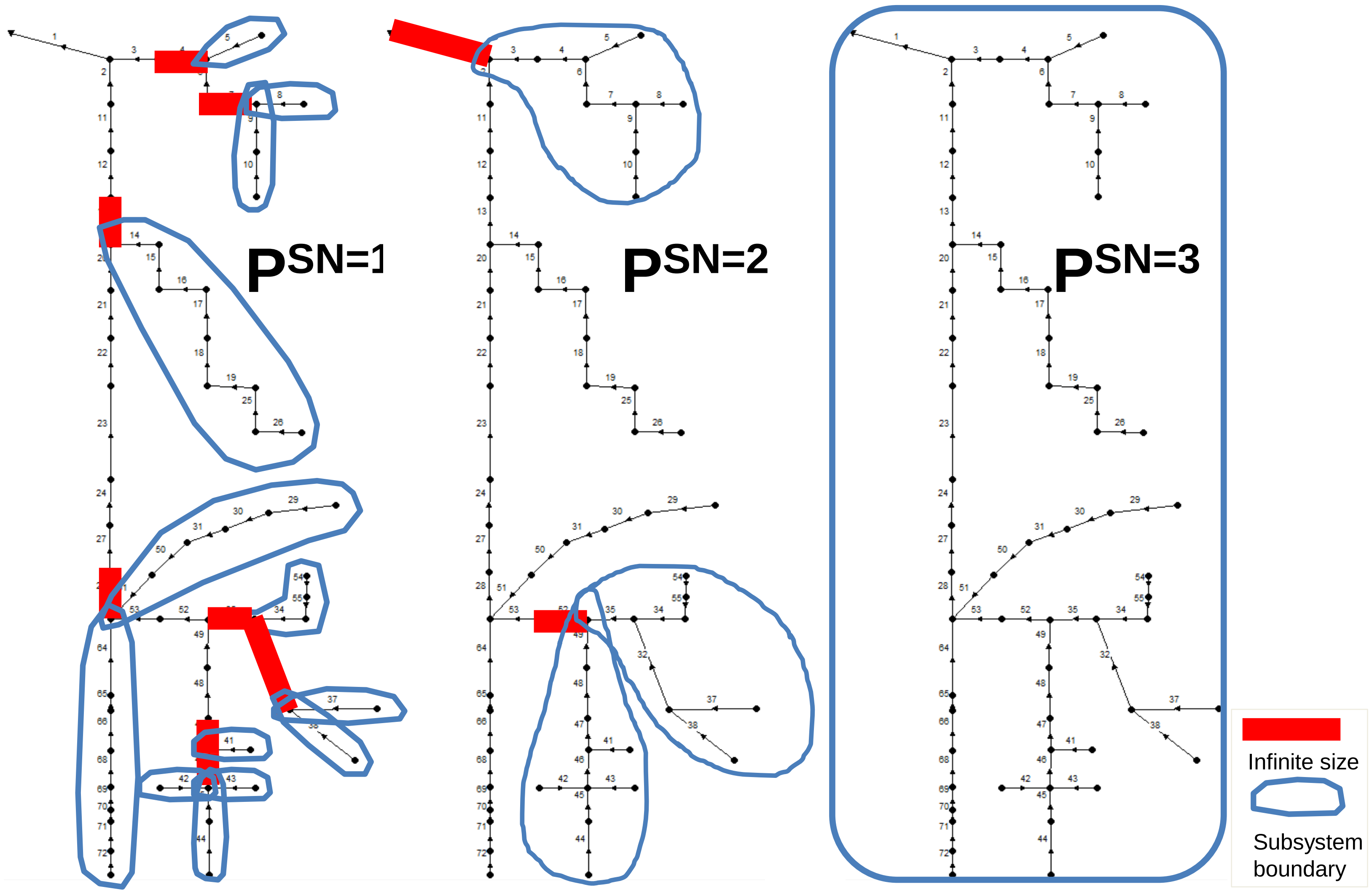
Nodes: 60 Conduits: 59

Simulation: Duration (7 h)
Flow routing step (5 s)
Reporting step (1 min)

Reference:
Rossman, L. A. (2006). STORM WATER MANAGEMENT MODEL QUALITY ASSURANCE REPORT: Dynamic Wave Flow Routing. Water Supply and Water Resources Division National Risk Management Research Laboratory Cincinnati, OH 45268, USA.


(A)
Outfall
05y32
13
05y36
23
05y41
05y44
64
(B)
Elevation (m)
Distance (m)
22
20
18
16
14
12
10
8
6
4
2
0
-2
2,500
2,000
1,500
1,000
500
0
(C)
Rainfall (mm/hr)
Elapsed Time (hours)
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2

Step.1 and .2: “Sewer branch order” and Network Decomposition



Step.3: Pipe Sizing

Initial pipe sizes: Default values

Decision variables: All pipes

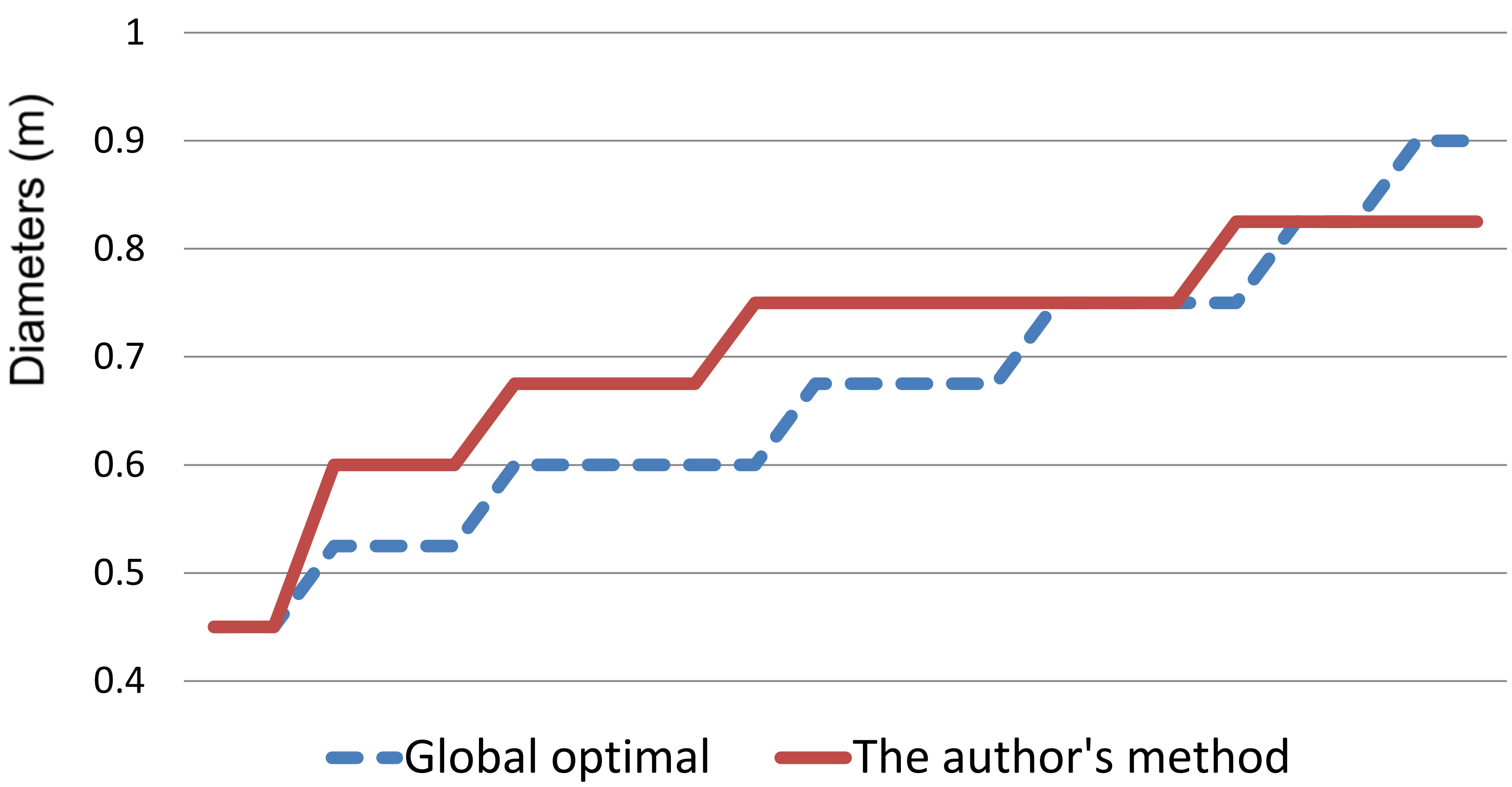
Stepsize and Costs: Con Cast Pipe Pricelist, 2012

Size (mm)	Class 50-D ($/m)	Size (mm)	Class 50-D ($/m)
300	65.9	1350	713.3
375	81.4	1500	872.4
450	83.9	1650	1,044.70
525	91.5	1800	1,262.40
600	131.5	1950	1,464.10
675	201.6	2100	1,680.00
750	265.7	2250	1,909.30
825	308.3	2400	2,234.70
900	369.8	2550	2,516.90
975	405.7	2700	2,793.30
1050	464.6	3000	3,420.60
1200	582.3		

Comparison between *the global optimal solution (by Brute Force)* and *authors' solution*

Pipe Sizes

PipeID	Initial Max. Depths (m)	Global optimal	Authors' method	PipeID	Initial Max. Depths (m)	Global optimal	Authors' method
25	0.600	0.675	0.675	47	0.500	0.825	0.825
26	0.600	0.675	0.675	48	0.600	0.900	**0.825**
29	0.400	0.450	0.450	49	0.600	0.900	**0.825**
30	0.450	0.600	0.600	64	0.450	0.750	0.750
31	0.500	0.600	0.600	65	0.450	0.750	0.750
41	0.300	0.525	**0.825**	66	0.450	0.750	0.750
42	0.230	0.525	**0.750**	68	0.450	0.750	0.750
43	0.300	0.525	**0.750**	69	0.300	0.675	**0.750**
44	0.300	0.450	**0.600**	70	0.300	0.675	0.675
45	0.500	0.600	**0.750**	71	0.300	0.600	**0.675**
46	0.500	0.825	0.825	72	0.300	0.600	**0.450**


1
0.9
0.8
0.7
0.6
0.5
0.4
Diameters (m)
Global optimal
The author's method

Costs

The authors' solution is about **2% higher** than the optimal solution

Computational Expense

Global optimal: 11 hrs

Authors' solution : 5 mins

Shortages of the authors' method

- Sensitive to the accuracy of hydrodynamic simulation

  e.g. "Infinite pipe" may amplify routing errors

- Affected by initial pipe sizes

4. Conclusions

- A method for flood protection-based sewer network design is developed;
- The reliability of the method is examined through a case study using a real world drainage system;
- The method might guarantee a near-optimal solution that is very close to the global optimal solution, while requires dramatically less computational effort than global optimization method;

Thanks for your attention! ☺