

‘Water-Wise Cities and Smart Water Systems’

Xi’an, China

11th – 13th September 2018

Global resilience analysis of water distribution systems for intervention development

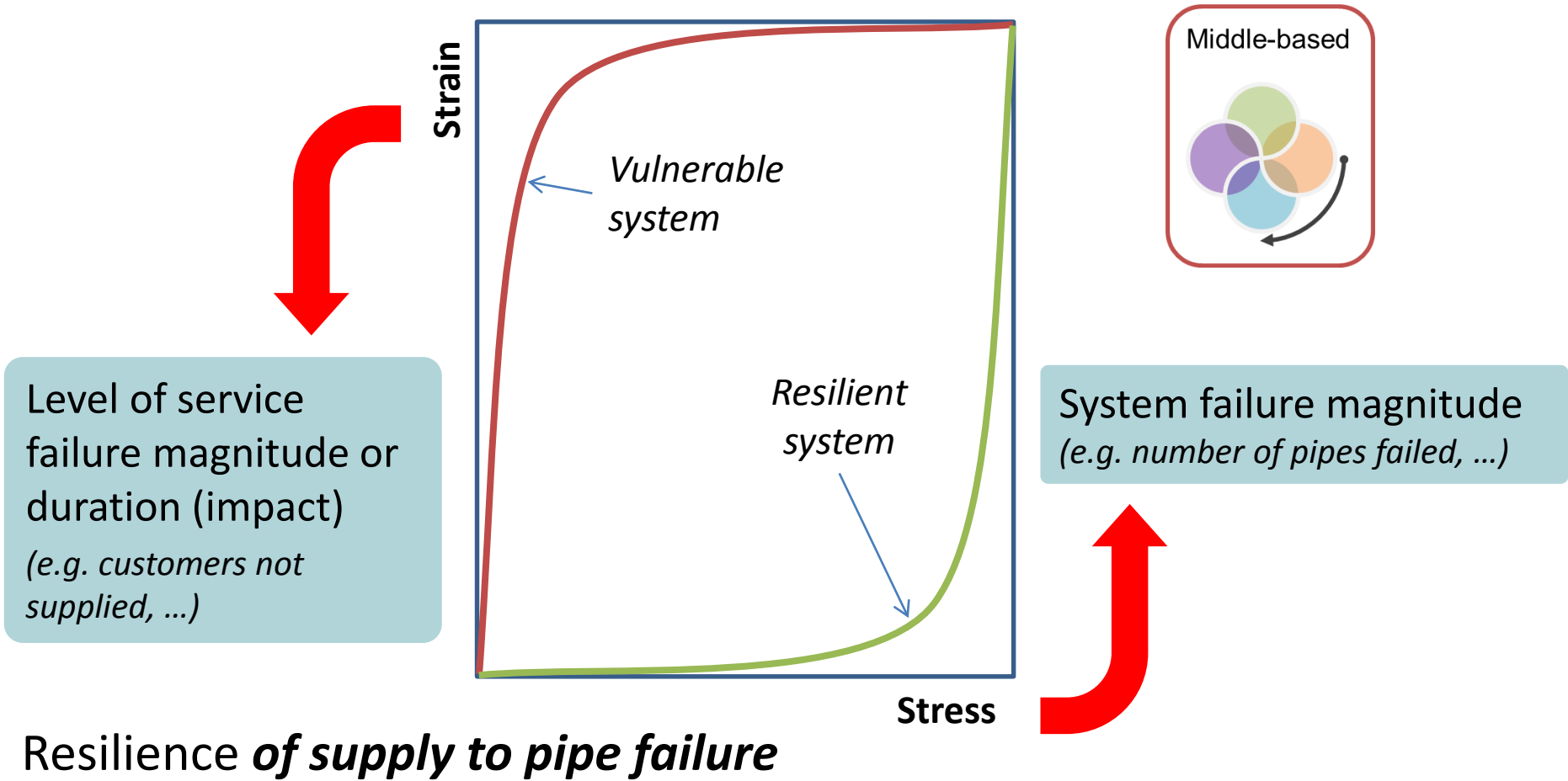
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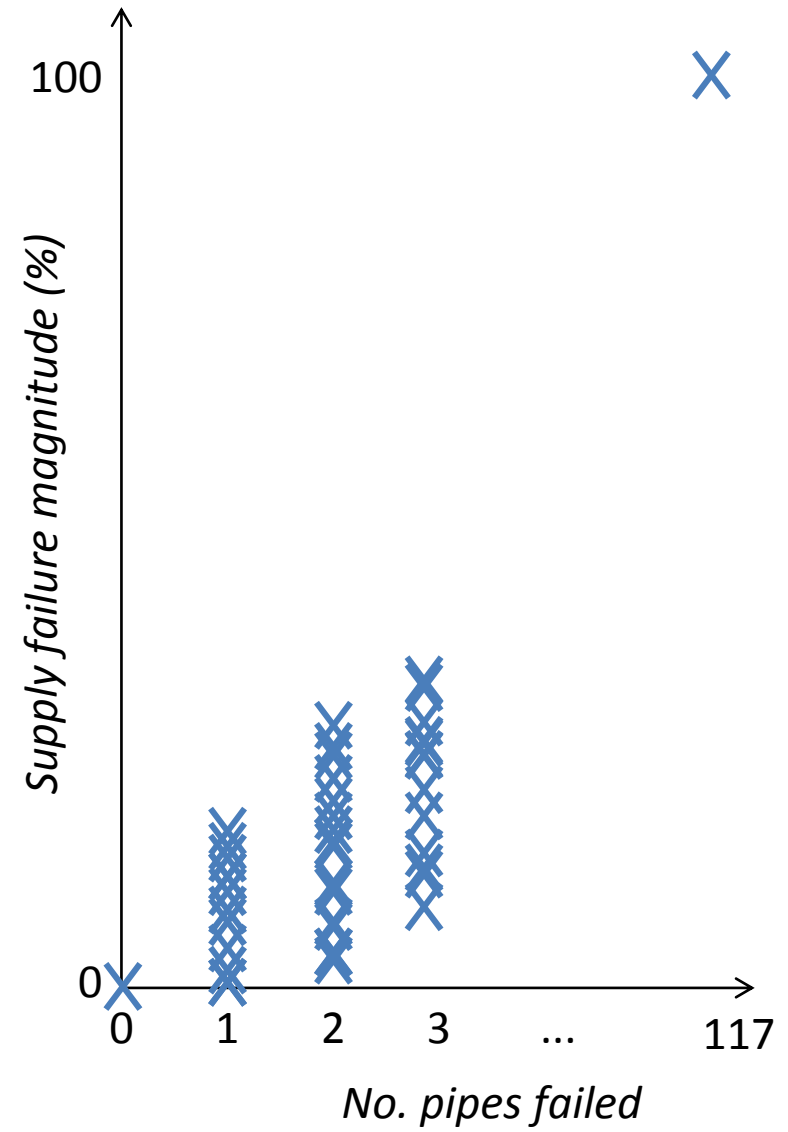
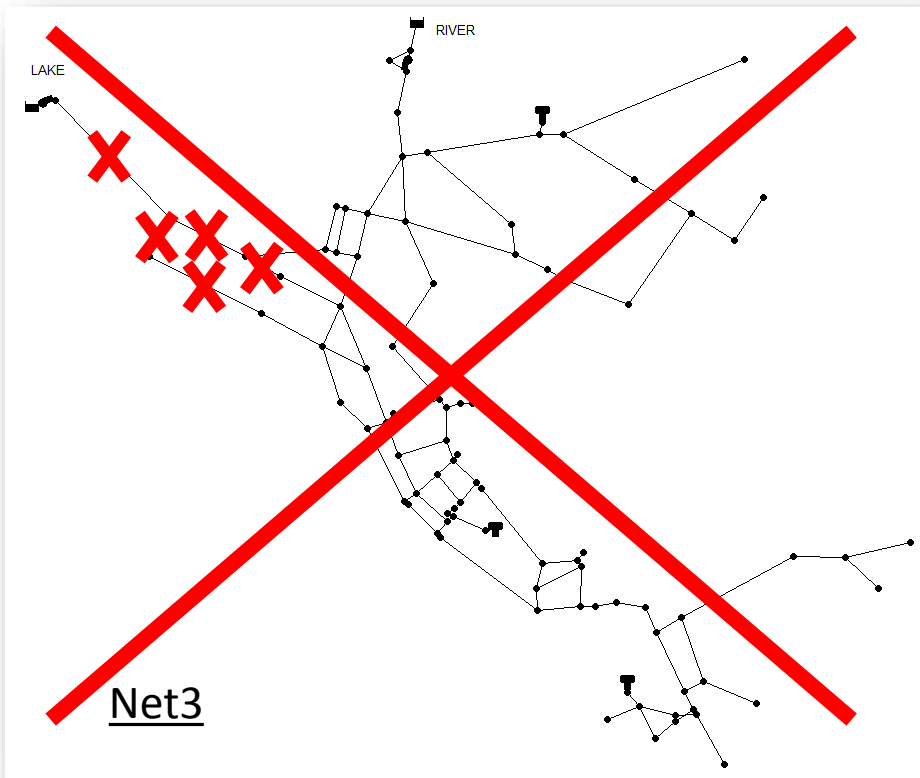
Outline

- Introduction to ***Global Resilience Analysis***
- ***A tool*** for Global Resilience Analysis
 - *Inputs and analysis types*
 - *Example outputs and intervention development*
 - *Intervention evaluation*
- ***Benefits***

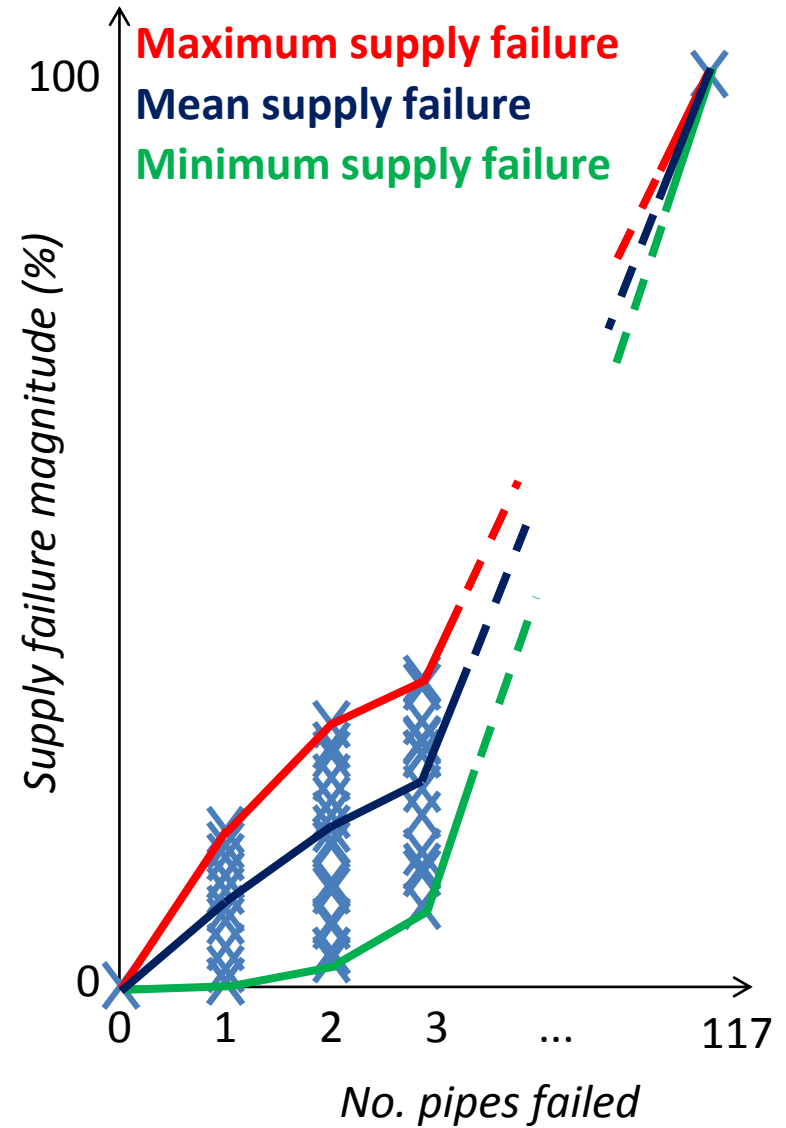
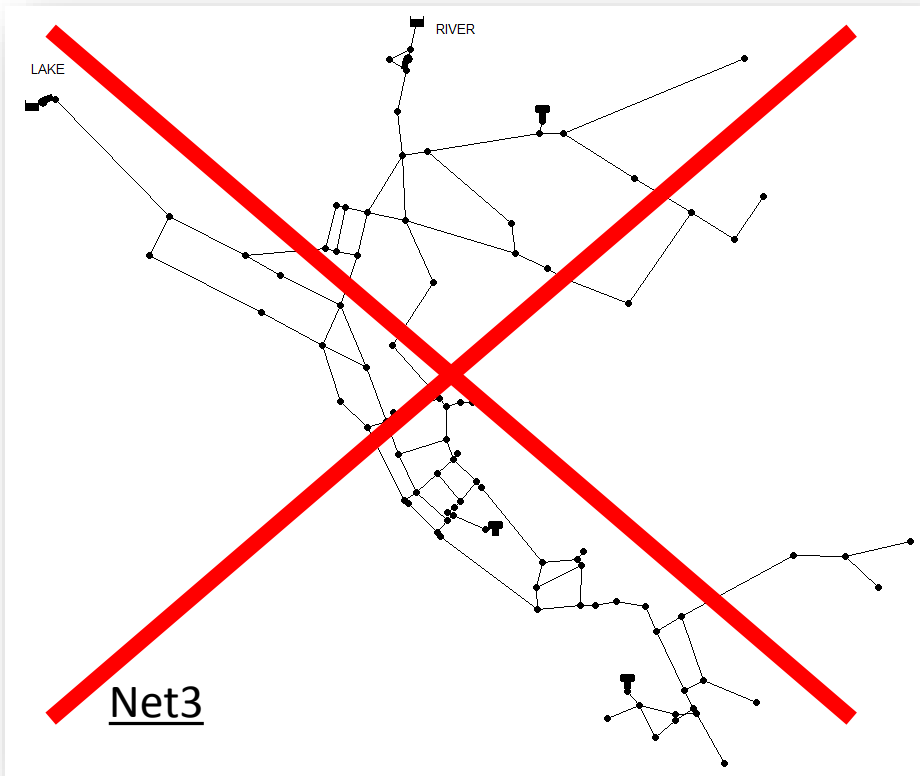
Global Resilience Analysis (GRA)



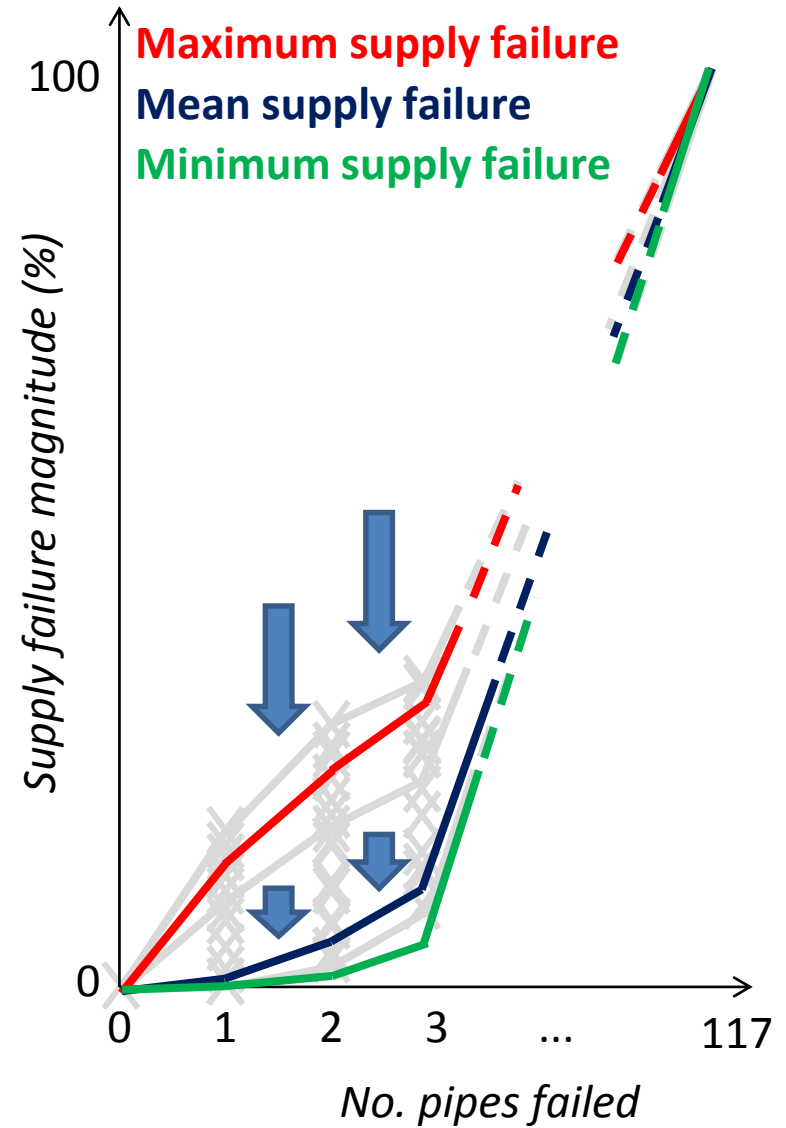
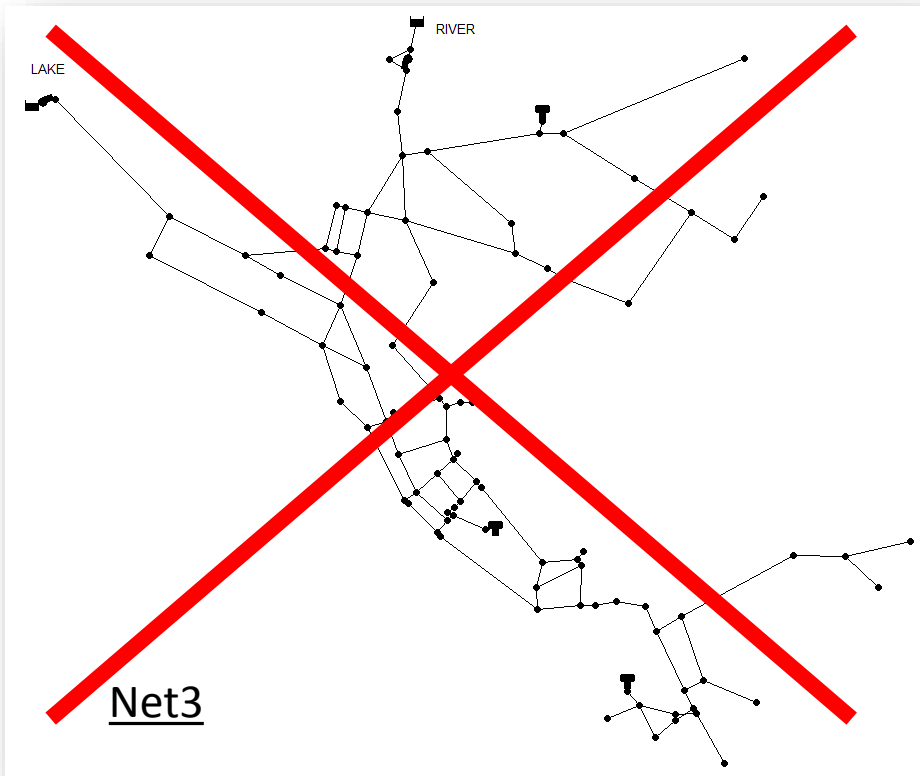
Response curve generation



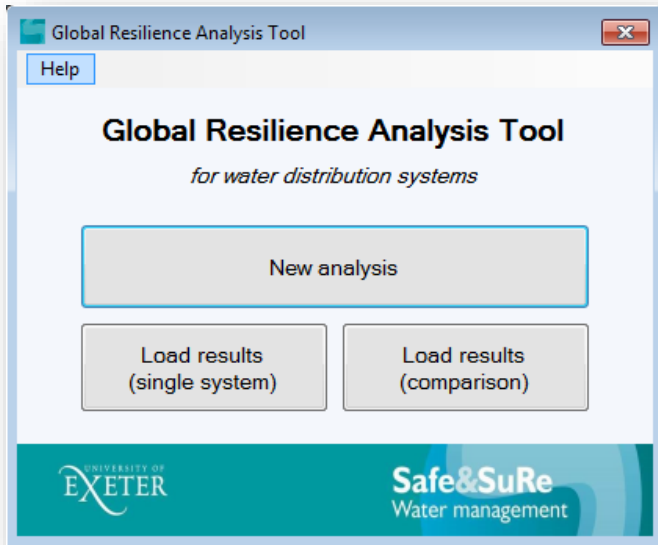
Response curve generation



Response curve generation



A tool for GRA

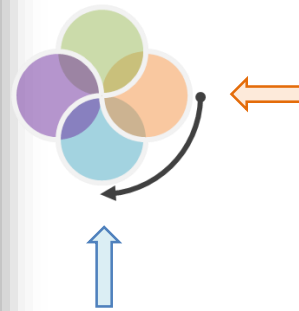


AIM: Develop a simple, user-friendly tool for global resilience analysis of water distribution systems

- Automate simulations required for global resilience analysis
- Aid interpretation and communication of the results
- Extract key findings from analysis
- Inform development of interventions

Inputs and analysis types

```
net3.inp - Notepad
File Edit Format View Help
[[TITLE]
EPANET Example Network 3
Example showing how the percent of Lake water in a dual-source
system changes over time.
[JUNCTIONS]
;ID          Elev          Demand        Pattern
10           147           0              3
15           32            1              3
20           129           0              3
35           12.5          1              4
40           131.9         0              4
50           116.5         0              4
60           0             0              4
601          0             0              4
61           0             0              4
101          42            189.95         4
103          43            133.2          4
105          28.5          135.37         4
107          22            54.64          4
109          20.3          231.4          4
111          10            141.94         4
113          2             20.01          4
115          14            52.1           4
117          13.6          117.71         4
119          2             176.13         4
120          0             0              4
121          -2            41.63          4
123          11            1              2
125          11            45.6           2
127          56            17.66          2
129          51            0              2
131          6             42.75          2
139          31            5.89           2
141          4             9.85           2
143          -4.5          6.2            2
145          1             27.63          2
147          18.5          8.55           2
149          16            27.07          2
151          33.5          144.48         2
153          66.2          44.17          2
157          13.1          51.79          2
159          6             41.32          2
161          4             15.8           2
163          5             9.42           2
164          5             0              2
166          -2            2.6            2
167          -5            14.56          2
169          -5            0              2
171          -4            39.34          2
173          -4            0              2
177          8             58.17          2
179          8             0              2
181          8             0              2
183          11            0              2
184          16            0              2
185          16            25.65          2
187          12.5          0              2
```



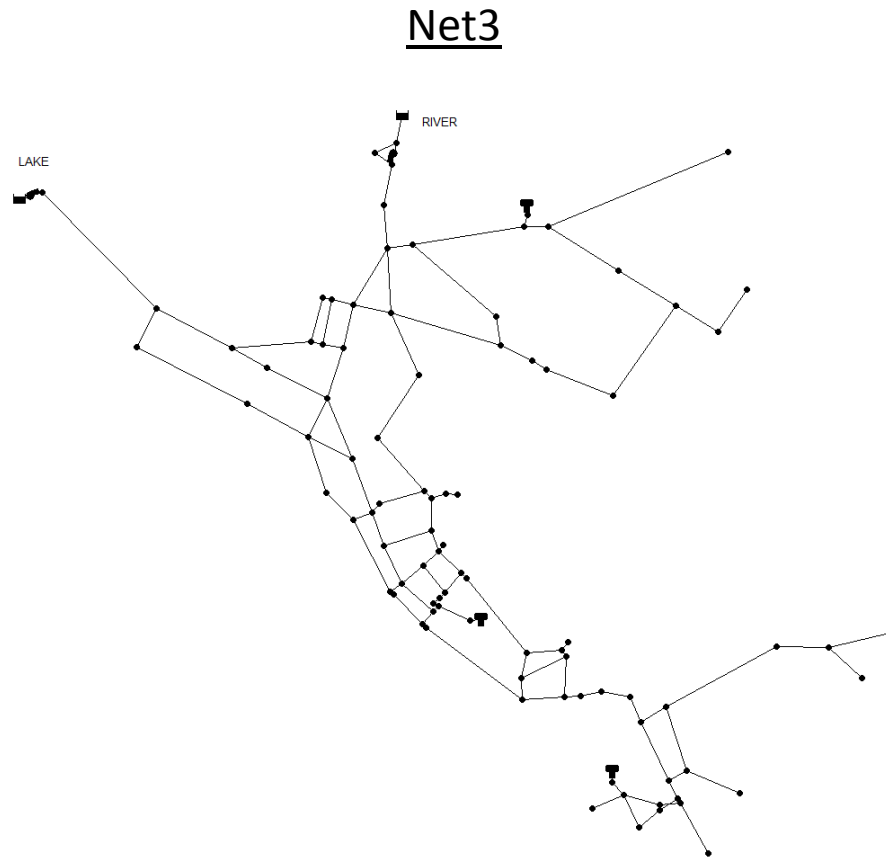
System failure mode:

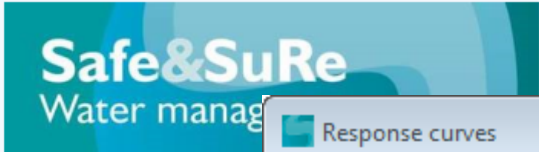
- Pipe failure
- Pump failure
- Demand increase
- Contaminant intrusion

Level of service requirements:

- Minimum allowable pressure
- Maximum allowable contaminant concentration

Example outputs and intervention development





Global Resilience Analysis Tool: Results Explorer

Water distribution system name: *net3_BC*

Settings

Measure of system failure:

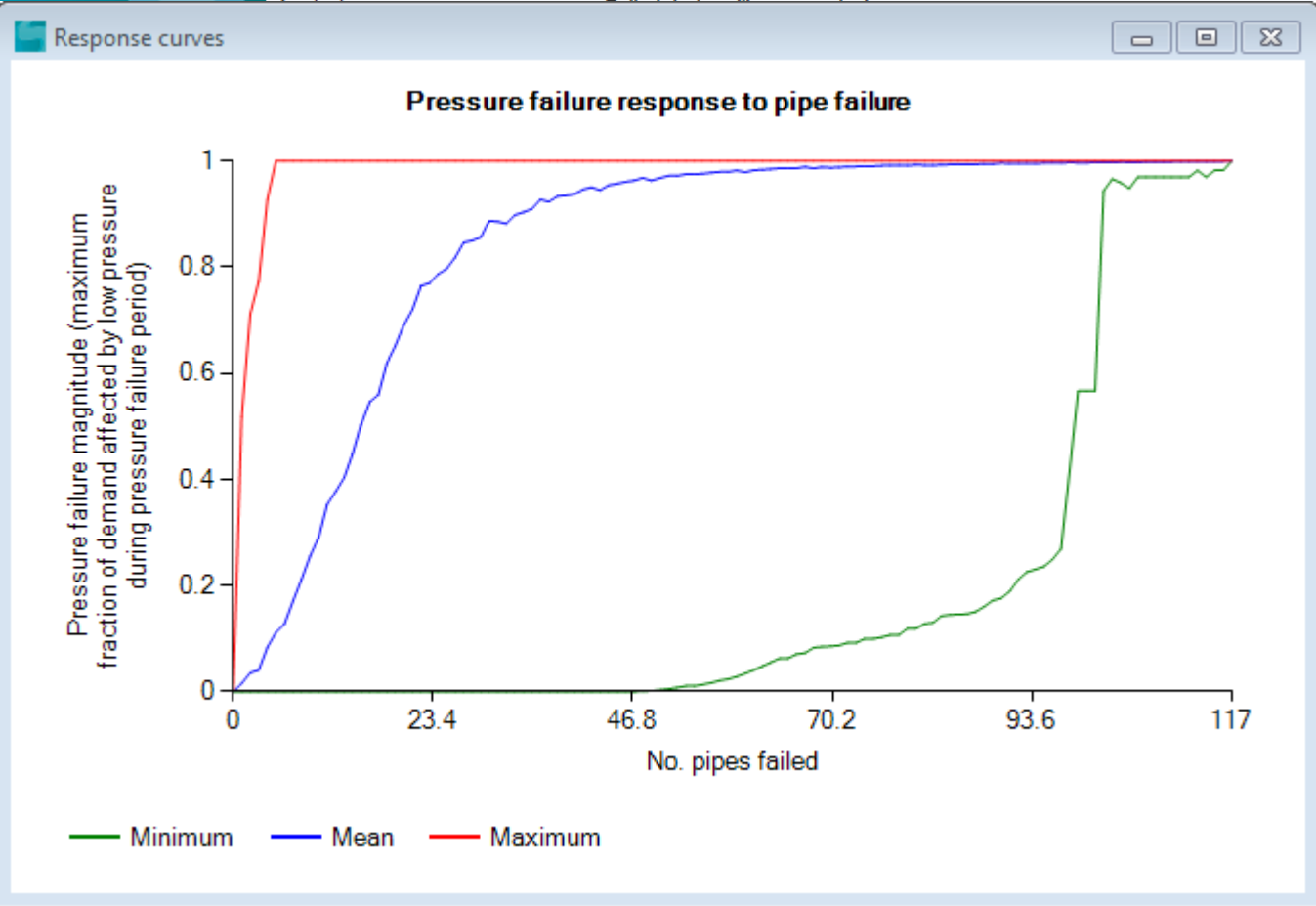
Level of service:

Level of service failure mode:

Scenario explorer view:

Scenario Explorer

No. pipes	Maximum pressure failure magnitude (fraction of demand)
0	0
1	0.5
2	0.7
3	0.7
4	0.7
5	0.7
6	0.8
7	0.9
8	0.9
9	1
10	1
11	1
12	1
13	1



[More detail...](#)

lines
curves





Global Resilience Analysis Tool: Results Explorer

Water distribution system name: *net3_BC*

Analysis type: *Full global resilience analysis*

System failure mode: *Pipe failure*

[More detail...](#)

Settings

Measure of system failure magnitude:

Level of service:

Level of service failure measure:

Scenario explorer view:

Actions

Map display mode:

Scenario identification

Pipe criticality under single pipe failure (with respect to selected settings)

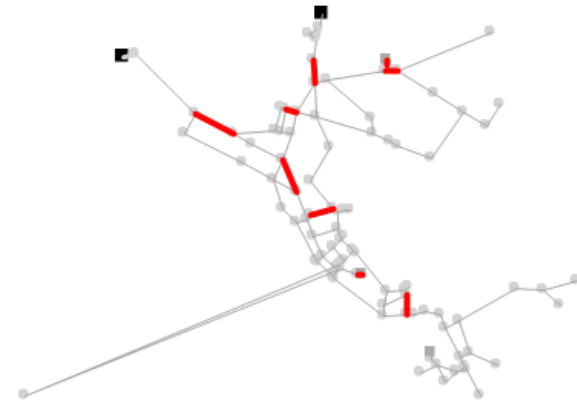
Scenario Explorer

	No. pipes	Max pressure failure magnitude (fraction)
	0	0
	1	0.5182
	2	0.7116
	3	0.7738
	4	0.7782
	5	0.7788
	6	0.8579
	7	0.9468
	8	0.9884
▶	9	1
	10	1
	11	1
	12	1
	13	1

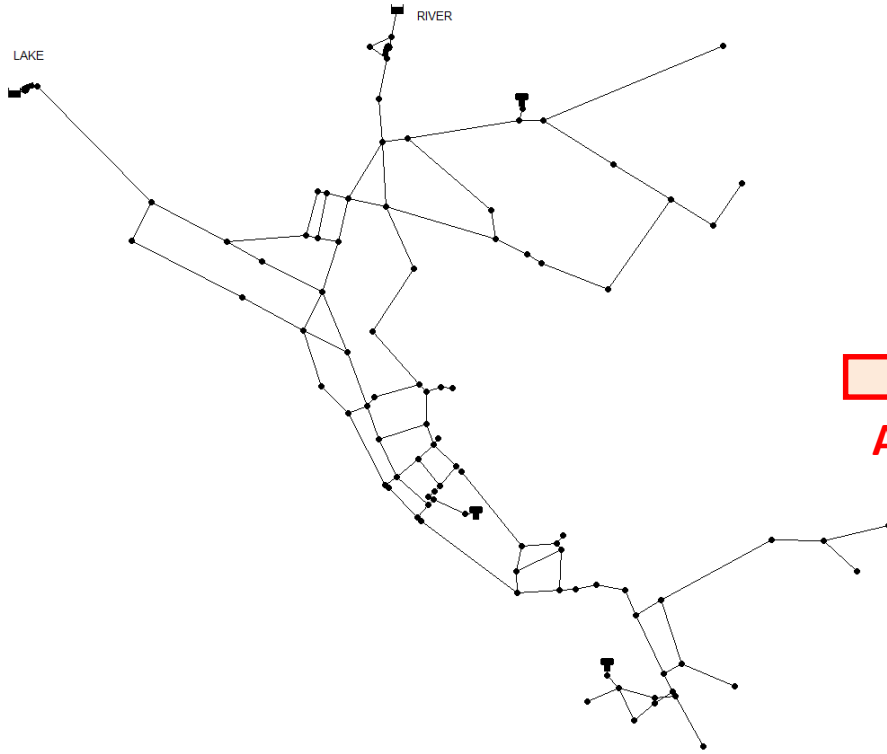


Map Layers

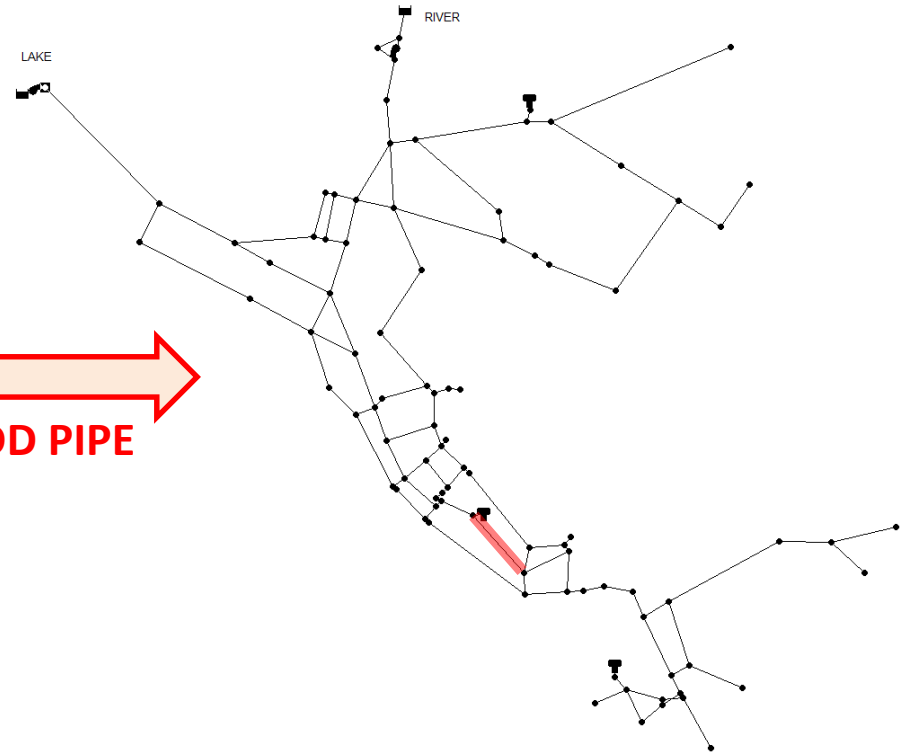
- Valve
- Pump
- Pipe
 - Not failed
 - Failed
- Reservoir
- Tank
- Junction



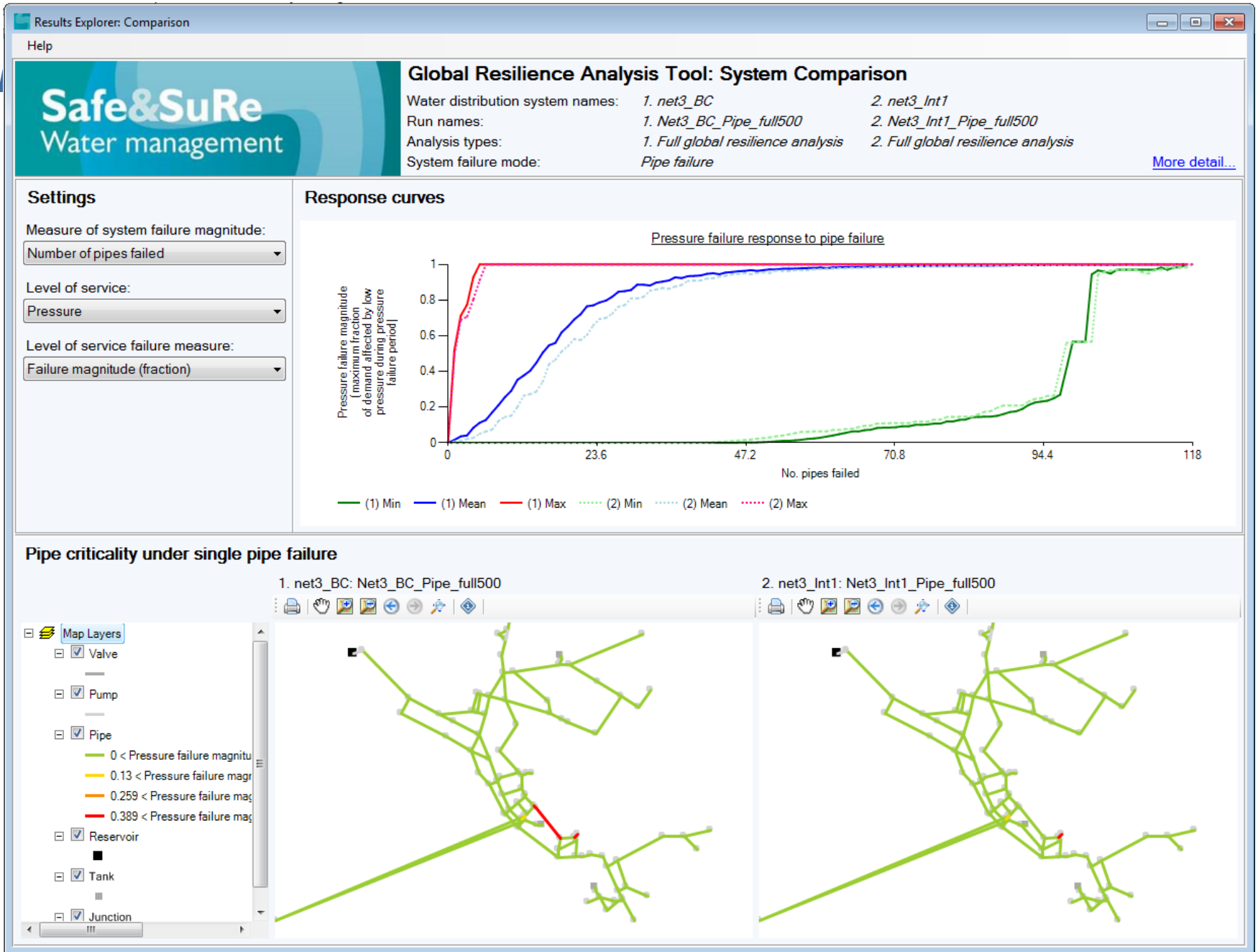
Net3: Base case



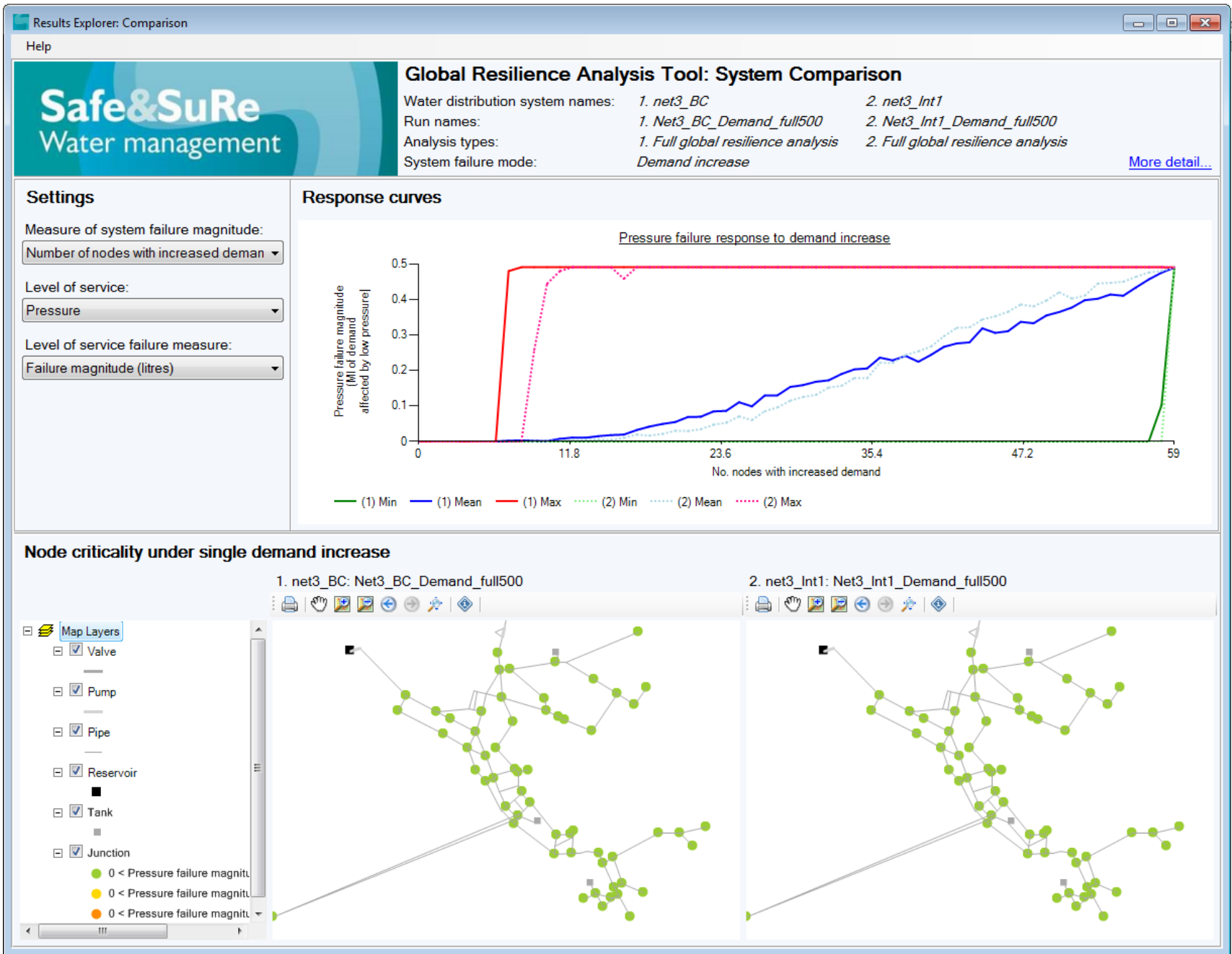
Net3: Intervention

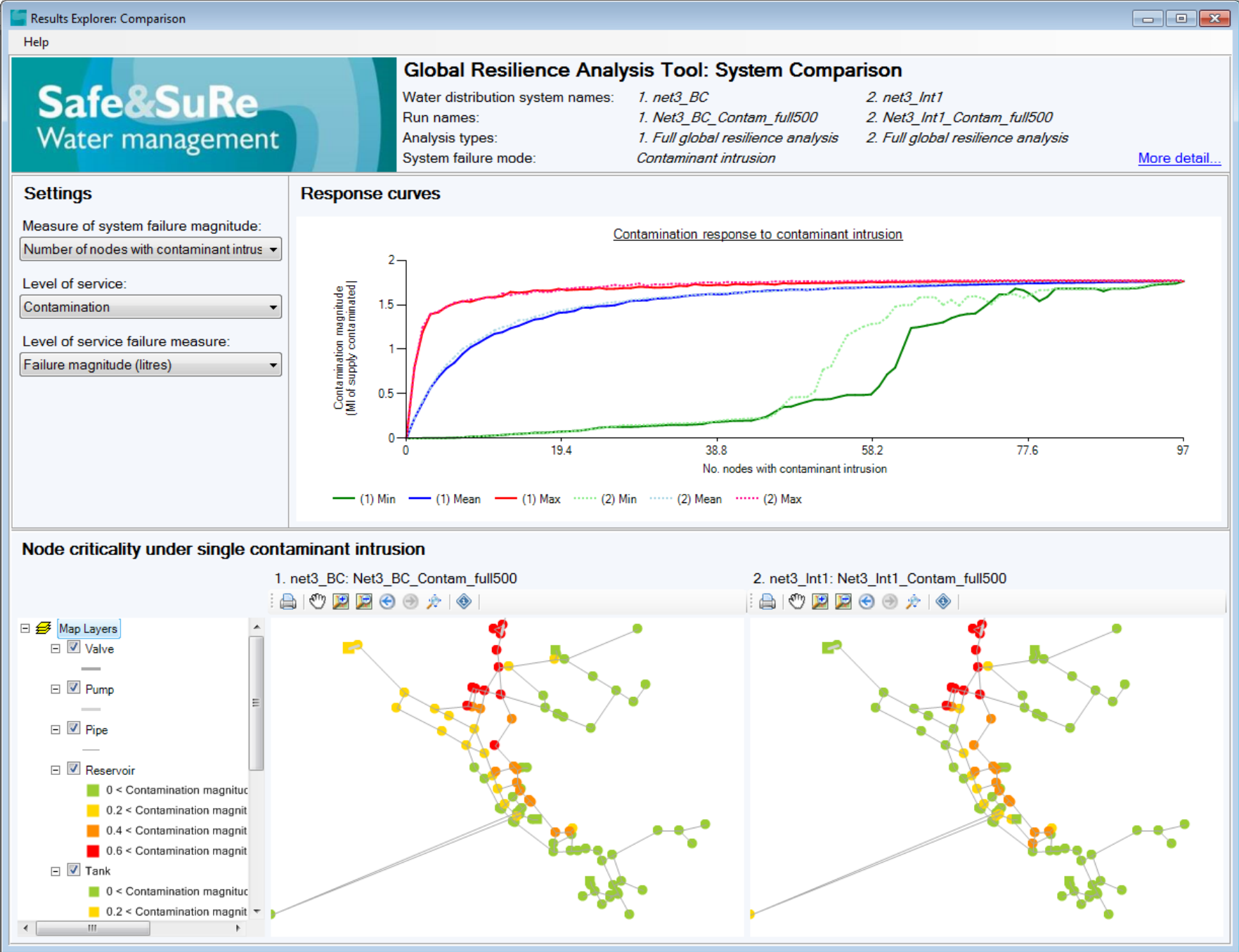


ADD PIPE



Resilience to demand increase





Benefits of the GRA tool

- ✓ *Automated global resilience analysis of a water distribution system, incorporating both probable and highly improbable (unknown probability) system failures*
- ✓ *Understanding of Epanet and system failure modelling not necessary*
- ✓ *Provides assessment of resilience to different system failure modes*
- ✓ *Critical components can be easily identified*
- ✓ *Interventions can be evaluated*

www.safeandsure.info

References

Diao, K., Sweetapple, C., Farmani, R., Fu, G., Ward, S. & Butler, D. (2018) Global resilience analysis of water distribution systems. *Water Research*, 106, 383-393.

Sweetapple, C., Diao, K., Farmani, R., Fu, G. & Butler, D. (2018). A tool for global resilience analysis of water distribution systems. 1st International WDSA/CCWI Joint Conference, Kingston, Ontario, Canada, July 23-25, 2018.