Simulation of the restoration process based on estimation of seismic damage to distribution pipes

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1 Background and Objective

● Progress in the Seismic Research Study

Osaka City Local Area Disaster Protection Plan : Reviewed seismic damage estimation

➡ Re-estimated the seismic damage to distribution pipes and water suspension areas occurred by scenario earthquake in Osaka city

➡ Reviewed emergent restoration and water supply plan

● Important to "business continuity"

Preparatory measures to maintain or restore water service in early stage after the earthquake

➡ Recognize required support scales to achieve our target of emergent water supply and restoration

Developed restoration process simulation from the occurrence of disaster to the end of restoration works

2 Restoration policy of Osaka Municipal Waterworks Bureau

Policy : Emergency water supply

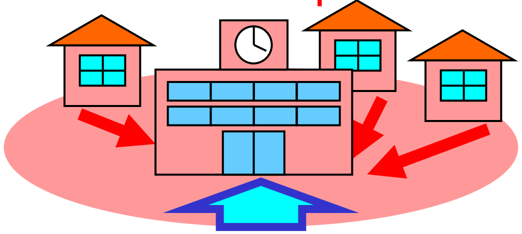
For citizens → Water supply to centers

Wide area shelters, accommodation shelters (schools, etc.), nearby city parks

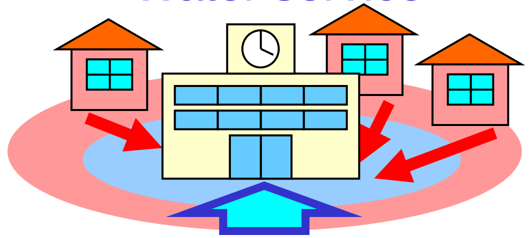
For important facilities → Delivery

Hospitals, daycare centers, etc.

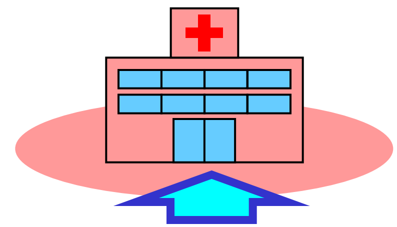
Water suspension



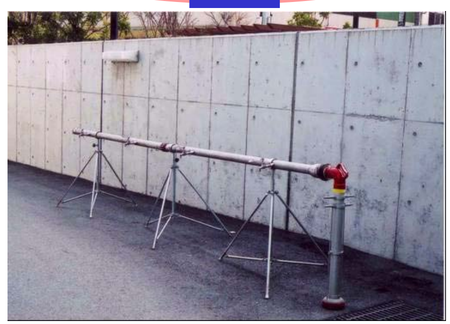
Water service



Water suspension



Temporary water tanks



Temporary water taps

Water delivery truck

Policy : Emergency restoration work of pipes

- Preferentially restore the pipeline routes leading to centers
- Complete restoration works within one month at maximum

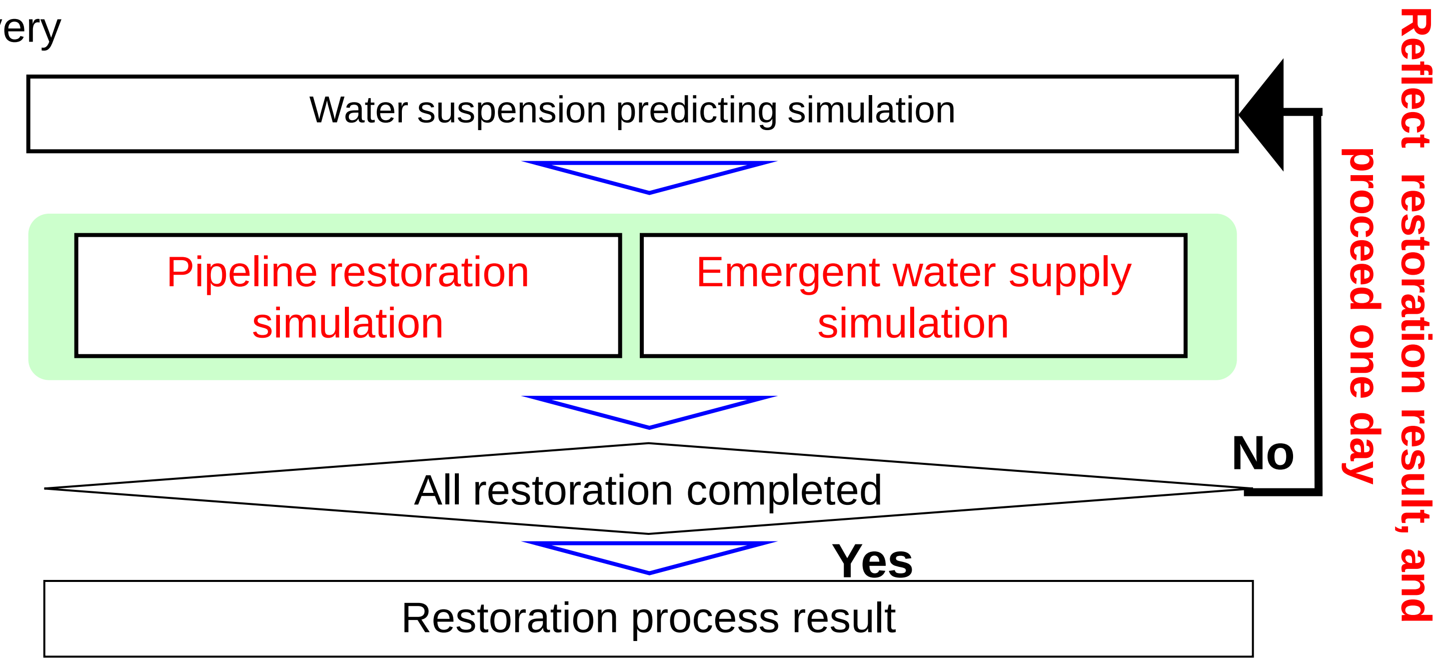
3 Outline of the restoration process simulation

4 Estimation of seismic damage to distribution pipes in the city area

5 Prediction of water suspension area in the city

6 Simulation of the restoration process just after the earthquake(case study)

Simulate the restoration process by repeating the following flow on each day from occurrence of the disaster to the end of restoration on the condition of our time objective (one month) for recovery



4 Estimation of seismic damage to distribution pipes in the city area

4-1 The seismic damage estimation formula

Re-established the seismic damage estimation formula for distribution pipes

Peak ground velocity

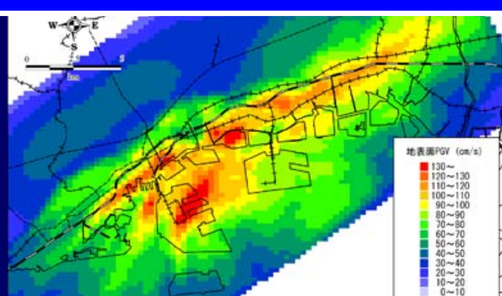
Potential of liquefaction

Pipe type / diameter

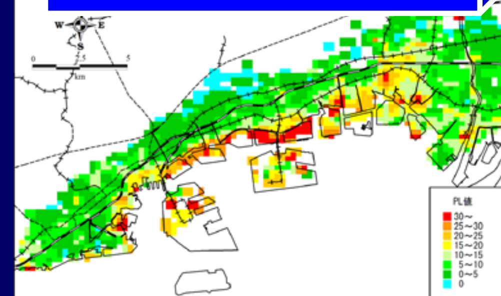
Seismic failure rate of distribution pipes

Use the data of the Kobe Earthquake in 1995

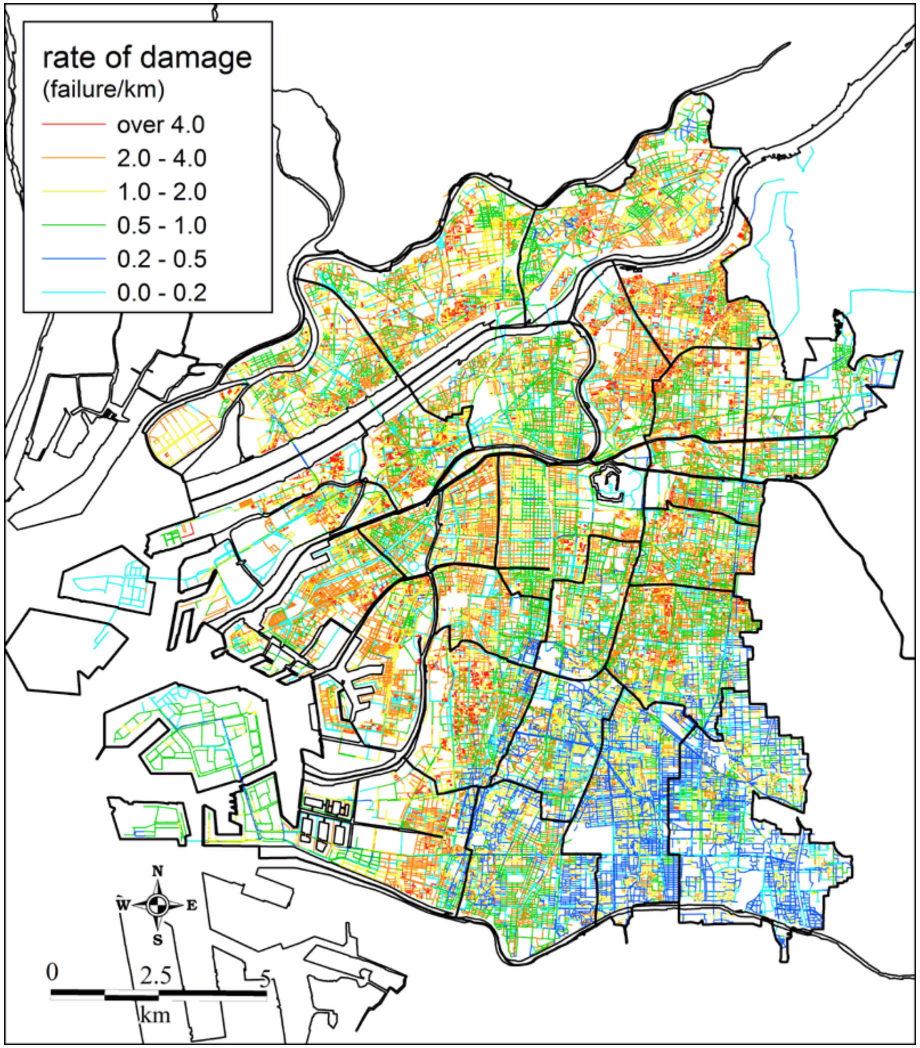
Peak ground velocity



Liquefaction



4-2 Result : Seismic failure rate of distribution pipes



The number of damaged pipelines came to about 5,900 points

◆ For the Uemachi fault earthquake, the largest damage of the earthquake scenarios considered in Osaka City

5 Prediction of water suspension area in the city

5-1 Prediction method of water suspension area in the city

- Estimated water suspension rate by grid, then predicted water suspension areas at first day after the earthquake
- Separately estimated water suspension in mainlines and in small pipes

Mainlines

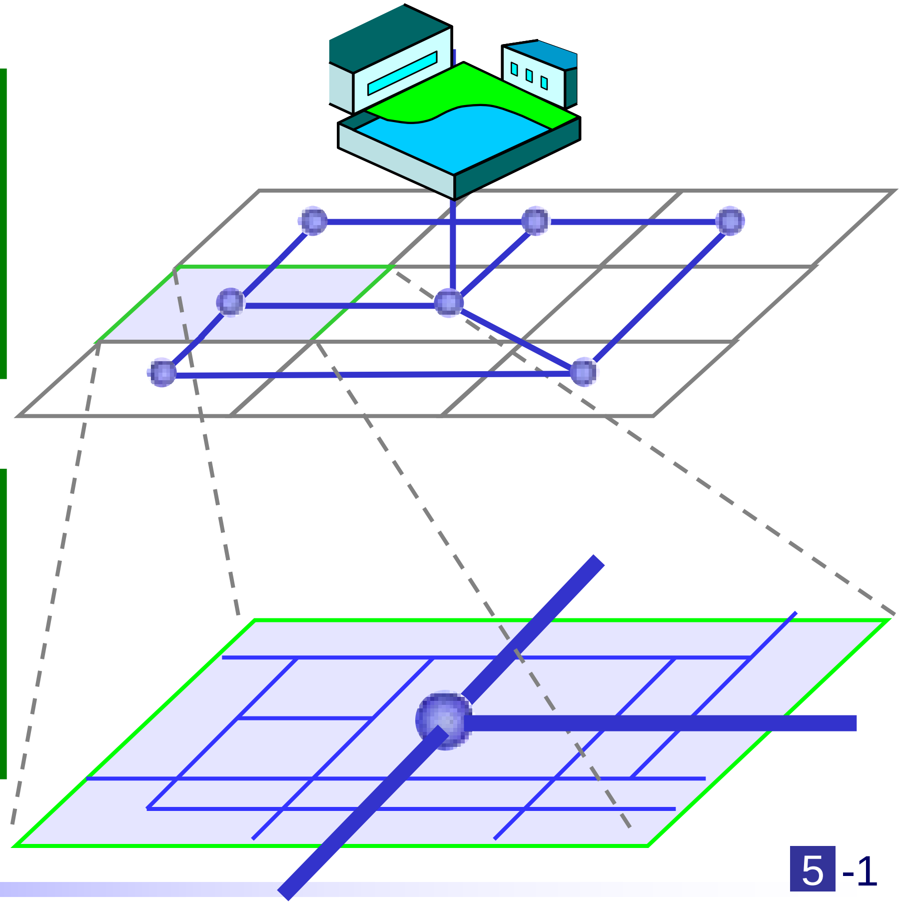
(distribution pipes of 400mm and more(diameter))

- Distribution network analysis considering leakage

Small pipes

(distribution pipes of less than 400mm(diameter))

- Empirical rules obtained from existent seismic damage



5-2 Estimation method of water suspension rate in mainlines

Set damaged points

Applied Monte Carlo Method

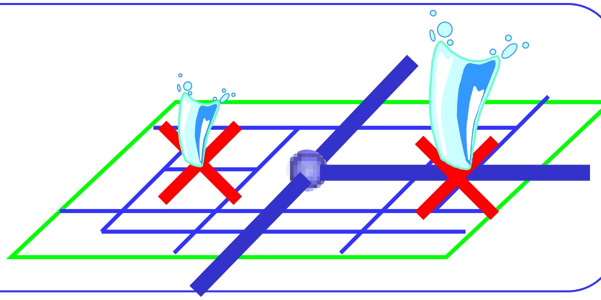
Randomly applied damage points with weighing the seismic failure rate

Distribution network analysis

Leakage amount data

Water pressure in mainlines

Set 5000 cases



Determination of water suspension in mainlines

（determination in each grid)

Mainline water suspension rate in each grid

$$D_i^{[m]} = N_i / 5{,}000$$

$D_i^{[m]}$: Water suspension rate at a node (i) in or nearest to a grid

N_i : The number of times that the node (i) became water suspension

5-3 Estimation method of water suspension rate in small pipes

- Estimated from empirical rules of existent seismic damage

  (correlation between seismic failure rate and water suspension rate)

$$y = 1 / \left(1 + 0.307 \cdot x^{-1.17}\right)$$

x : Average seismic failure rate of distribution pipes（points / km）

y : Water suspension rate at first day after earthquake (%)

Calculated water suspension rate in each grid

↓

Small pipes water suspension rate in each grid

5-4 Combined water suspension rate in mainlines and small pipes

- Estimated water suspension rate from mainlines and small pipes water suspension rate

Formula to combine the water suspension rates

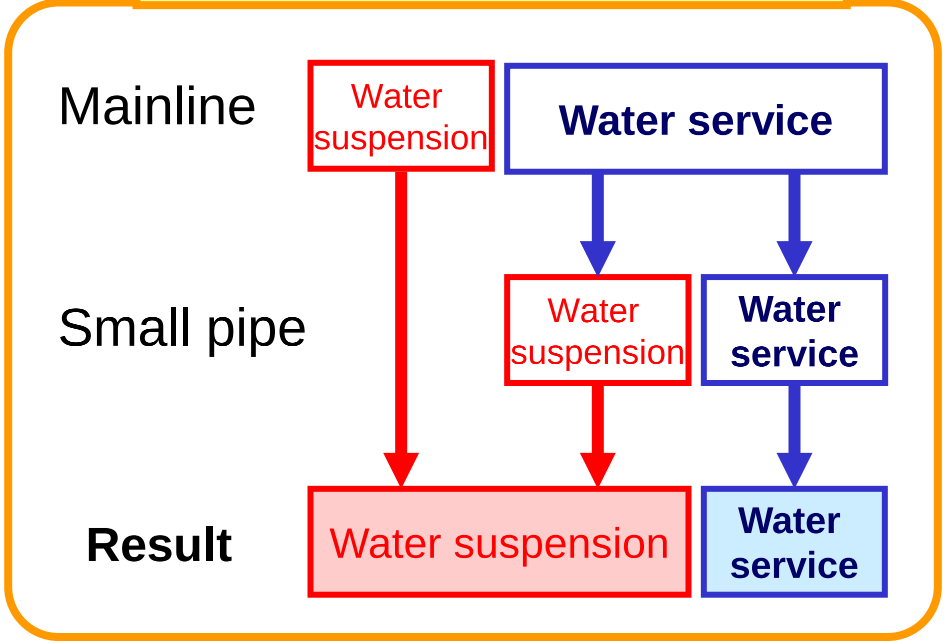
$$D = D^{[m]} + (1 - D^{[m]}) \cdot D^{[b]}$$

D : Water suspension rate

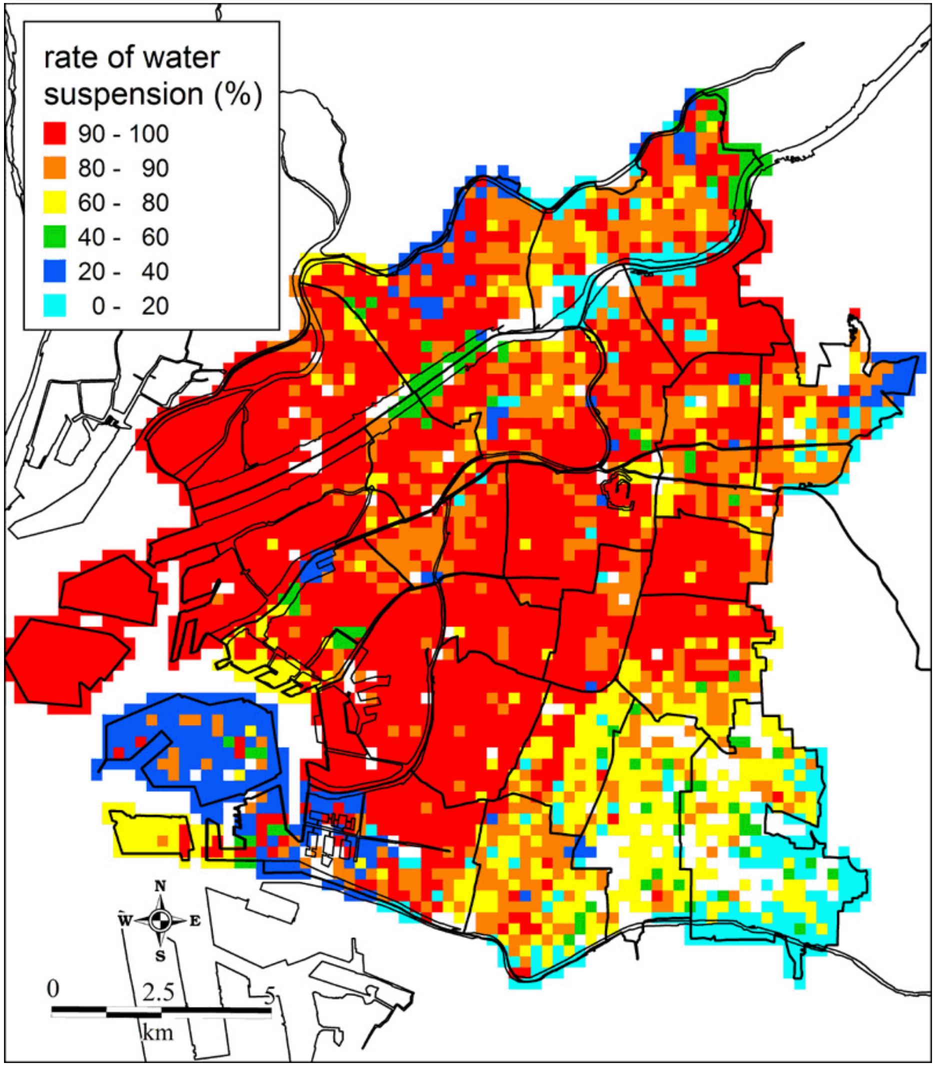
$D^{[m]}$: Mainline water suspension rate

$D^{[b]}$: Small pipes water suspension rate

Concept of the formula



5-5 Result : water suspension area



First day from earthquake

The water suspension rate in the city was 77%

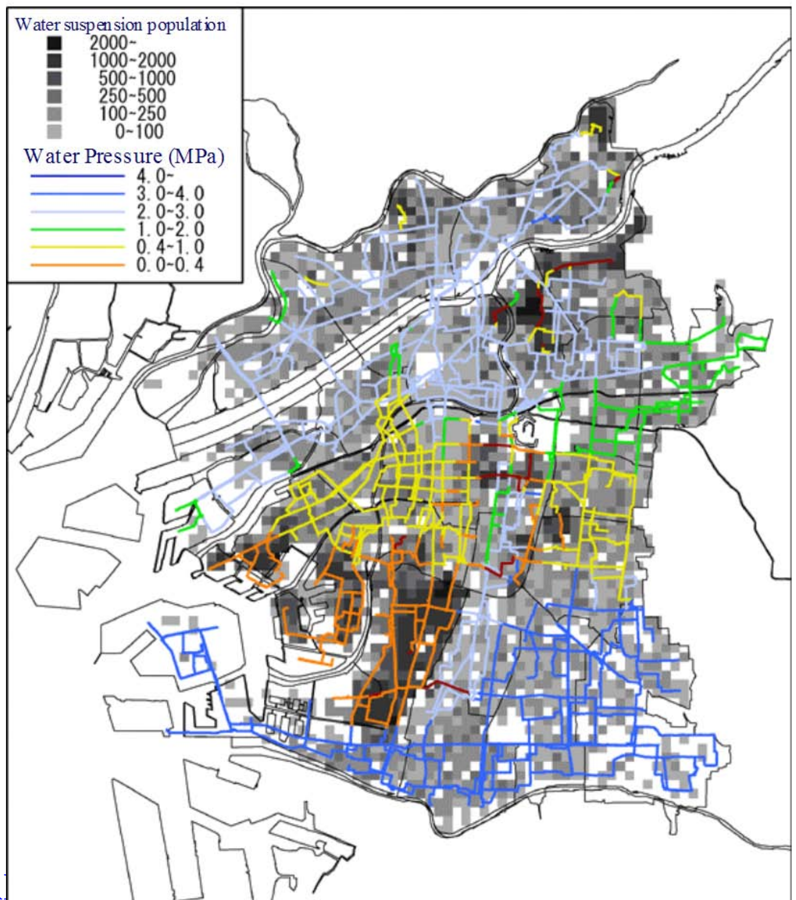
For the Uemachi fault earthquake, the largest damage of the earthquake scenarios considered in Osaka City

6 Simulation of the restoration process just after the earthquake

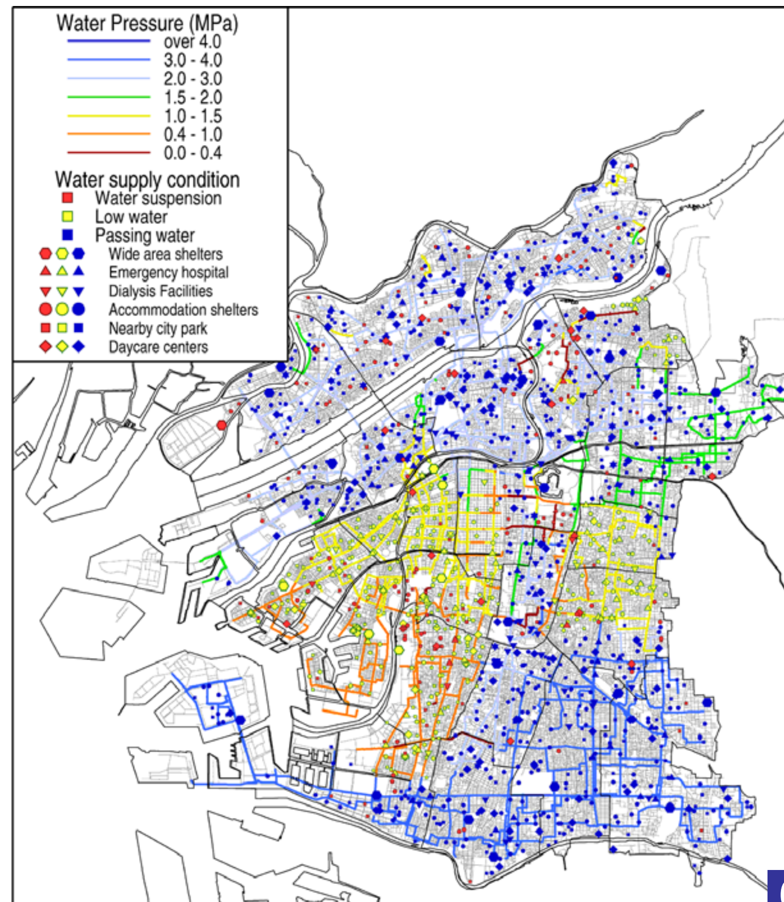
Estimated the transition of the population in water suspension, the emergency water supply centers, and of the amount of temporal water supply during the recovery time after the earthquake

6-1 Water suspension prediction results (3rd day after earthquake)

Water suspension population in a grid



Water suspension situation in centers



6-2 Simulation of emergency restoration work of pipes

Point on the simulation of emergency restoration work of pipes

● Preferentially restore the pipeline routes leading to centers and mainlines

● Restoration speed per one party

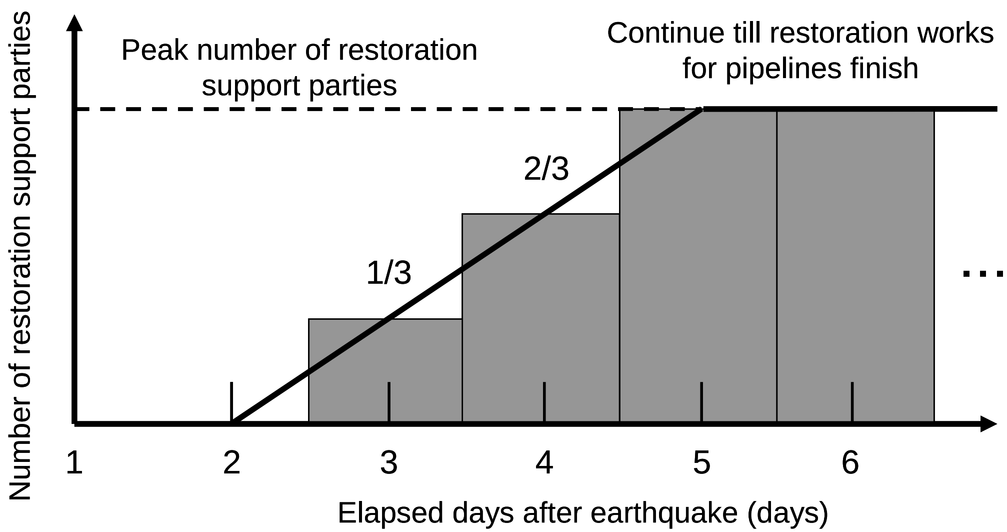
Mainline restoration	0.25 point / day
Small pipe restoration	2 points / day

◆ Assumed according to our past achievements

● Restoration organization

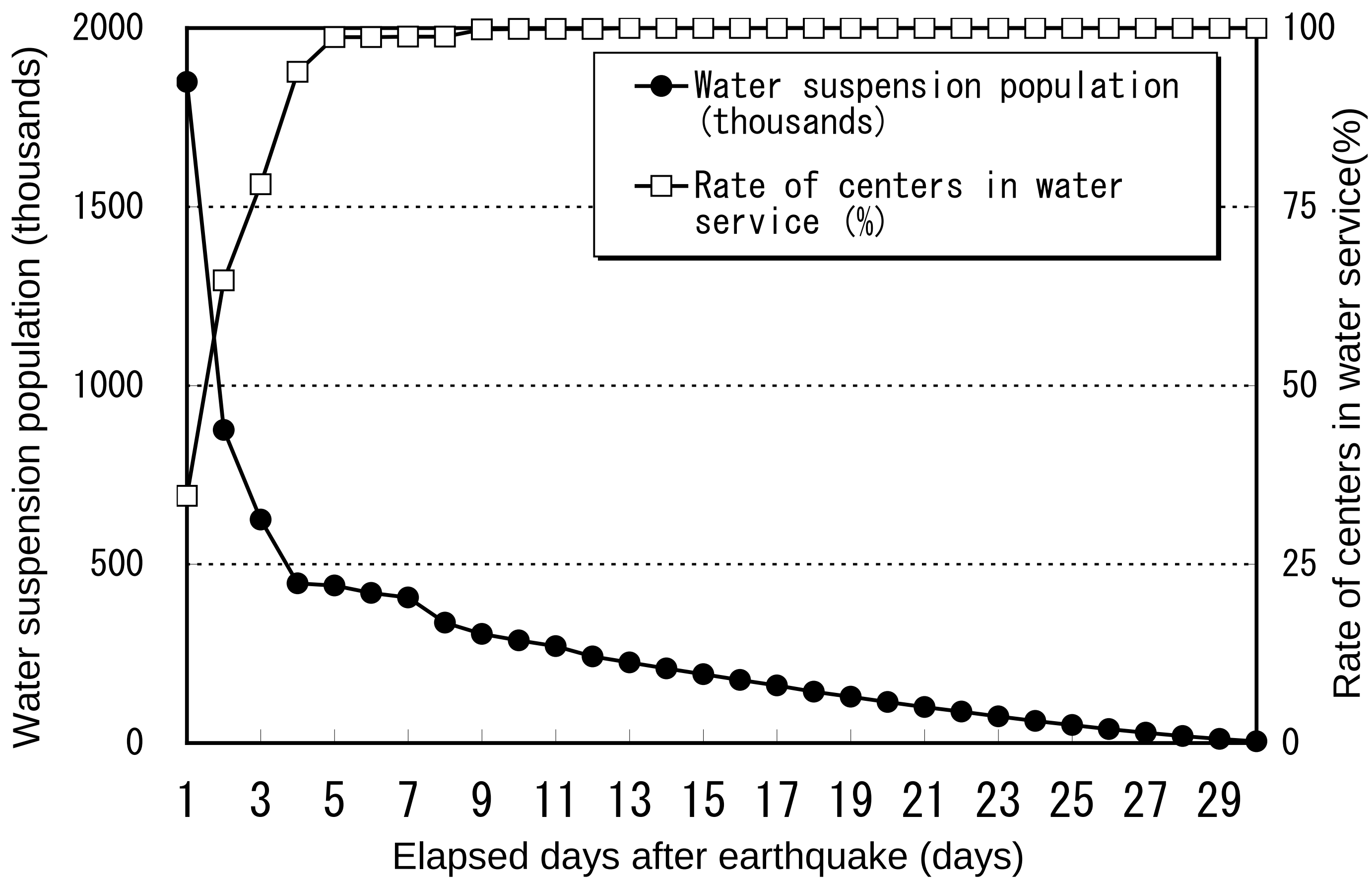
■ 28 parties from our city

■ Assumed that support parties would arrive in 3 to 5 days after earthquake



● Complete restoration works within one month at maximum

6-3 Result : Simulation of emergency restoration work of pipes



- Owing to preferentially restoration in mainlines and the pipeline leading to the centers, water suspension population dramatically improved.
- Ensured preferential water supply for centers (water service in all centers became normal within 9 days from the earthquake)

6-4 Simulation of emergency water supply

Point on the simulation of emergency water supply

● Supply a required water amount according to the water suspension situation in the city

● Required water amount

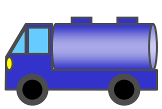
○ **For citizens** Required water amount = Water suspension population **x** Unit water amount

Days elapsed after earthquake	Target water unit amount	Water conveying distance for citizens
In 3 days	3 L/person a day	Within approximately 1 km
In 10 days	20 L/person a day	Within approximately 250 m
In 21 days	100 L/person a day	Within approximately 100 m
From 22nd days	250 L/person a day	Within approximately 100 m

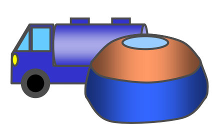
○ **For important facilities** (hospitals etc) Required water amount = Number of facilities **x** Unit water amount for each facility

● Emergent water supply measures

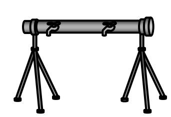
○ **Determined capability of each emergency water supply measure**



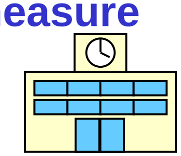
Delivery by trucks



Temporary tanks



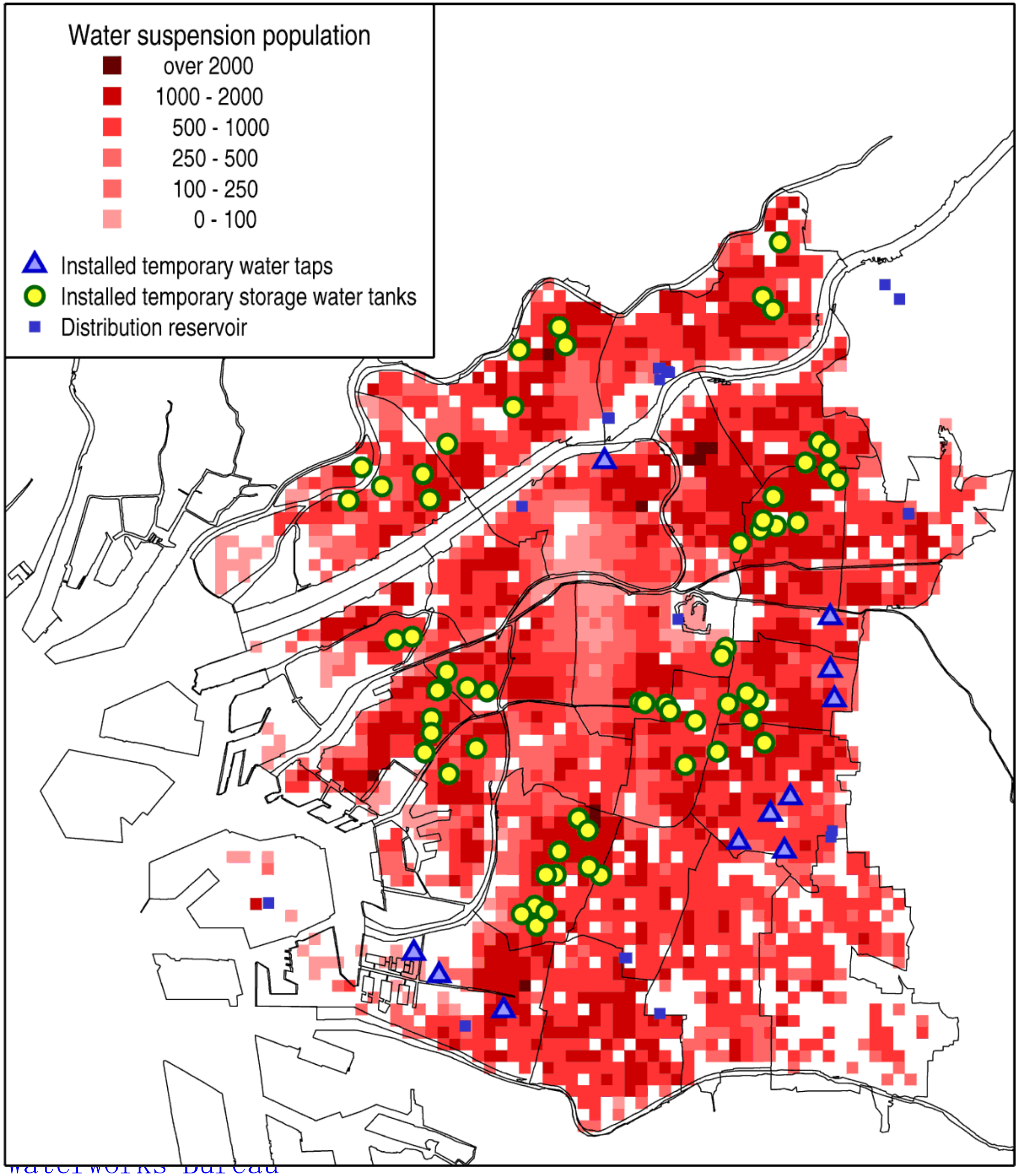
Temporary taps



Water taps in shelters

etc.

6-5
Result : 1

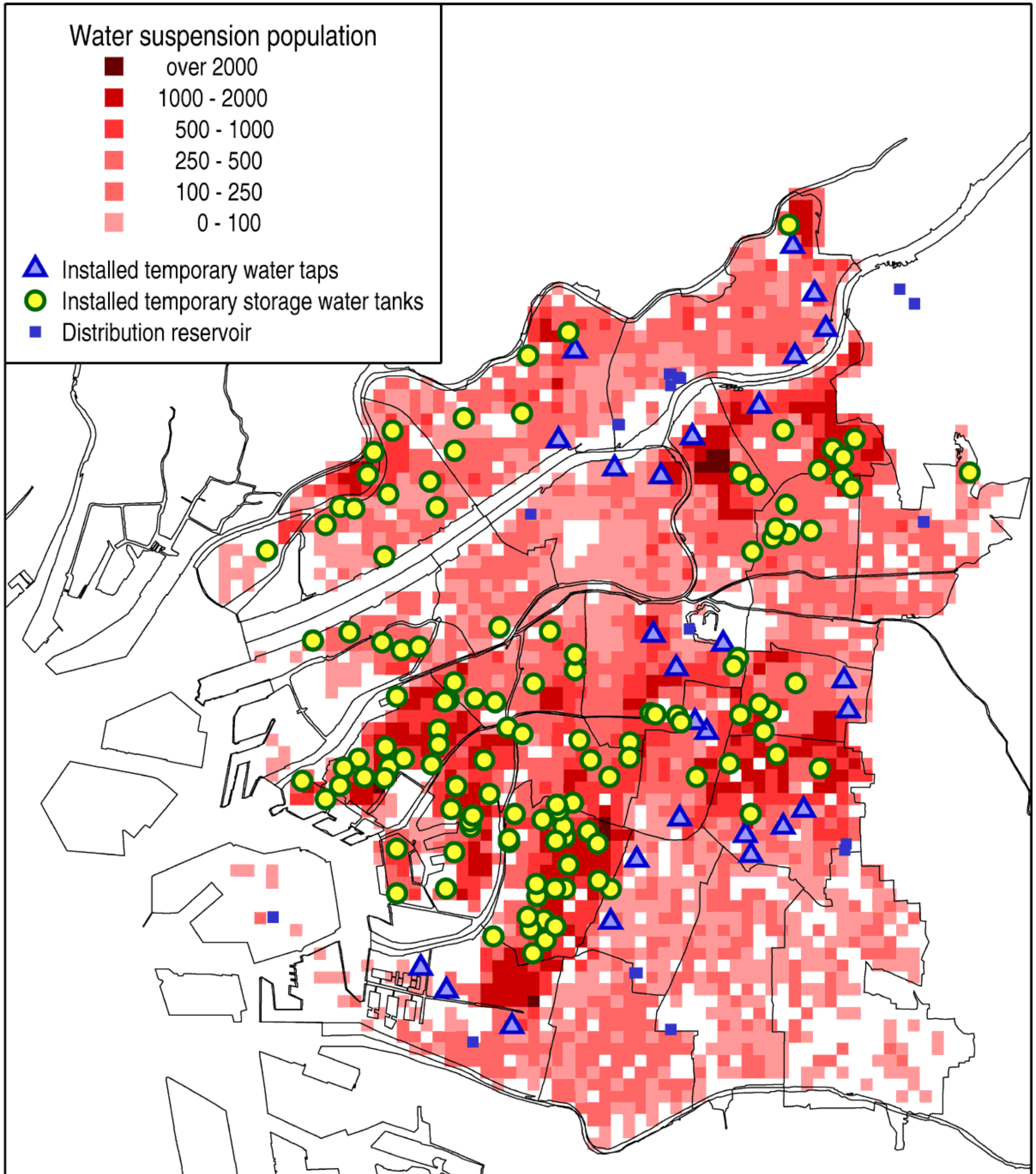


Required water amount 3L/person a day

Water conveying distance for citizens 1000m

First day from earthquake

6-6 Result : 2

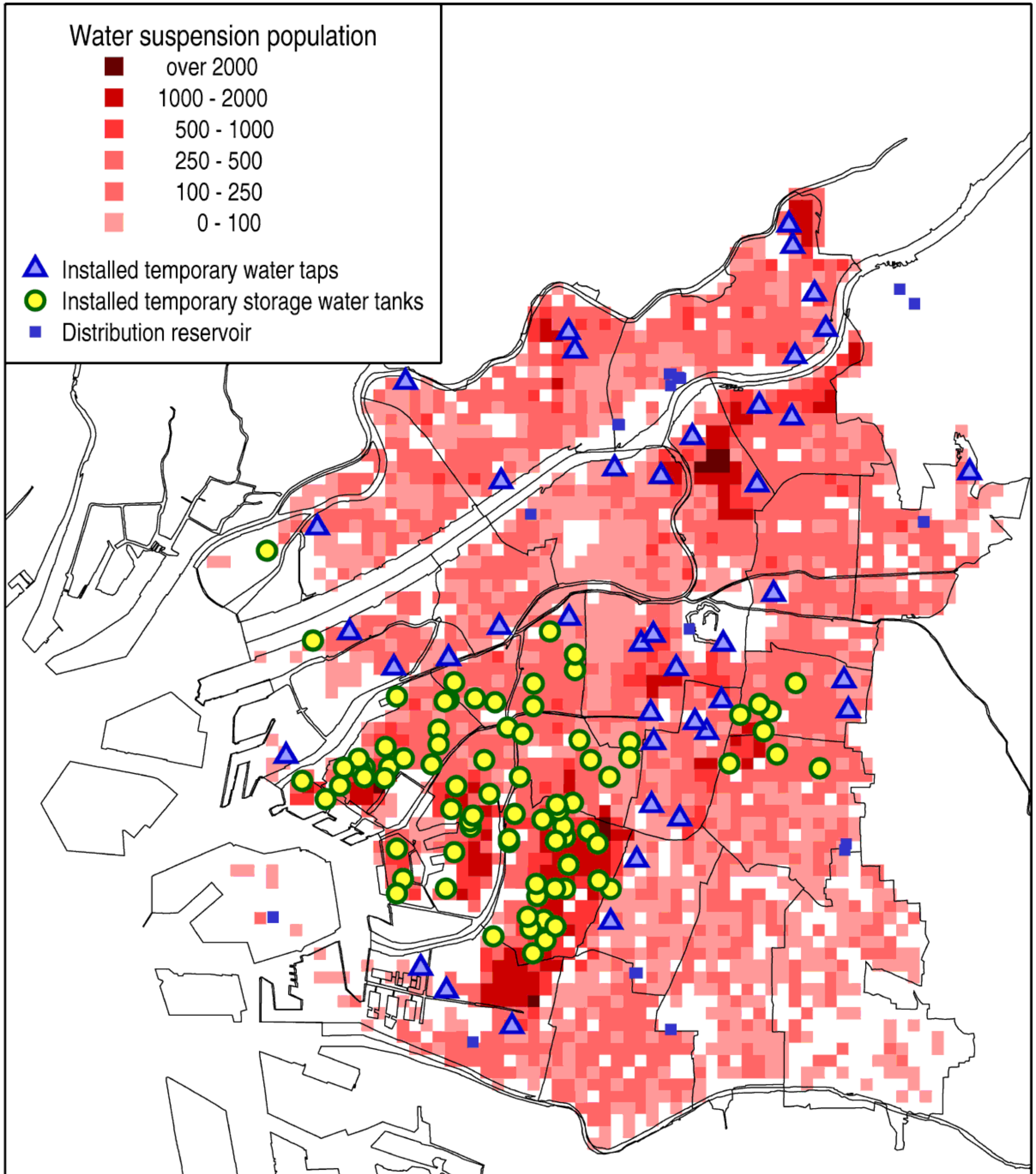


Required water amount 3L/person a day

Water conveying distance for citizens 1000m

2nd day from earthquake

6-7 Result : 3



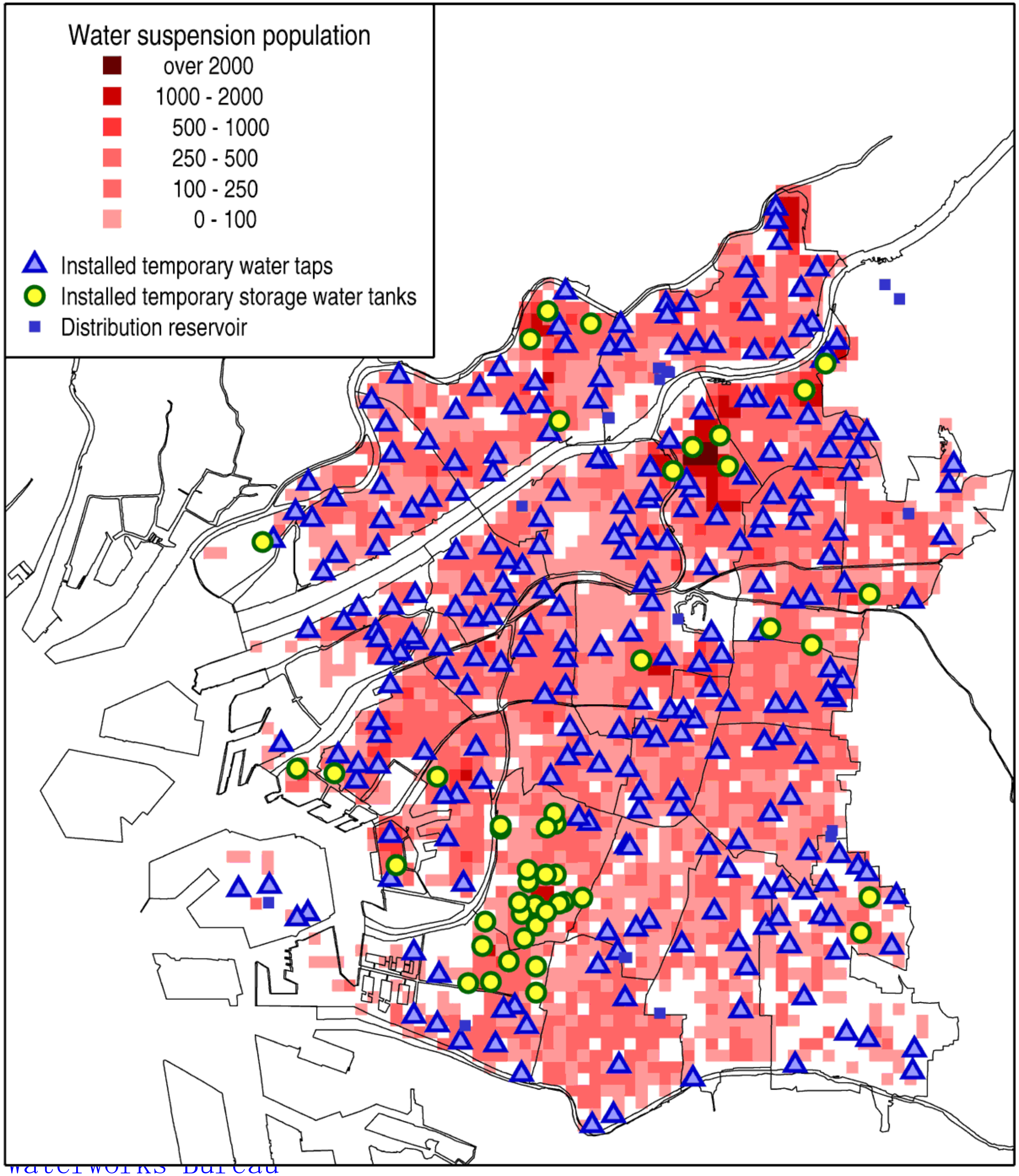
Required water amount 3L/person a day

Water conveying distance for citizens 1000m

3rd day from earthquake

6-8

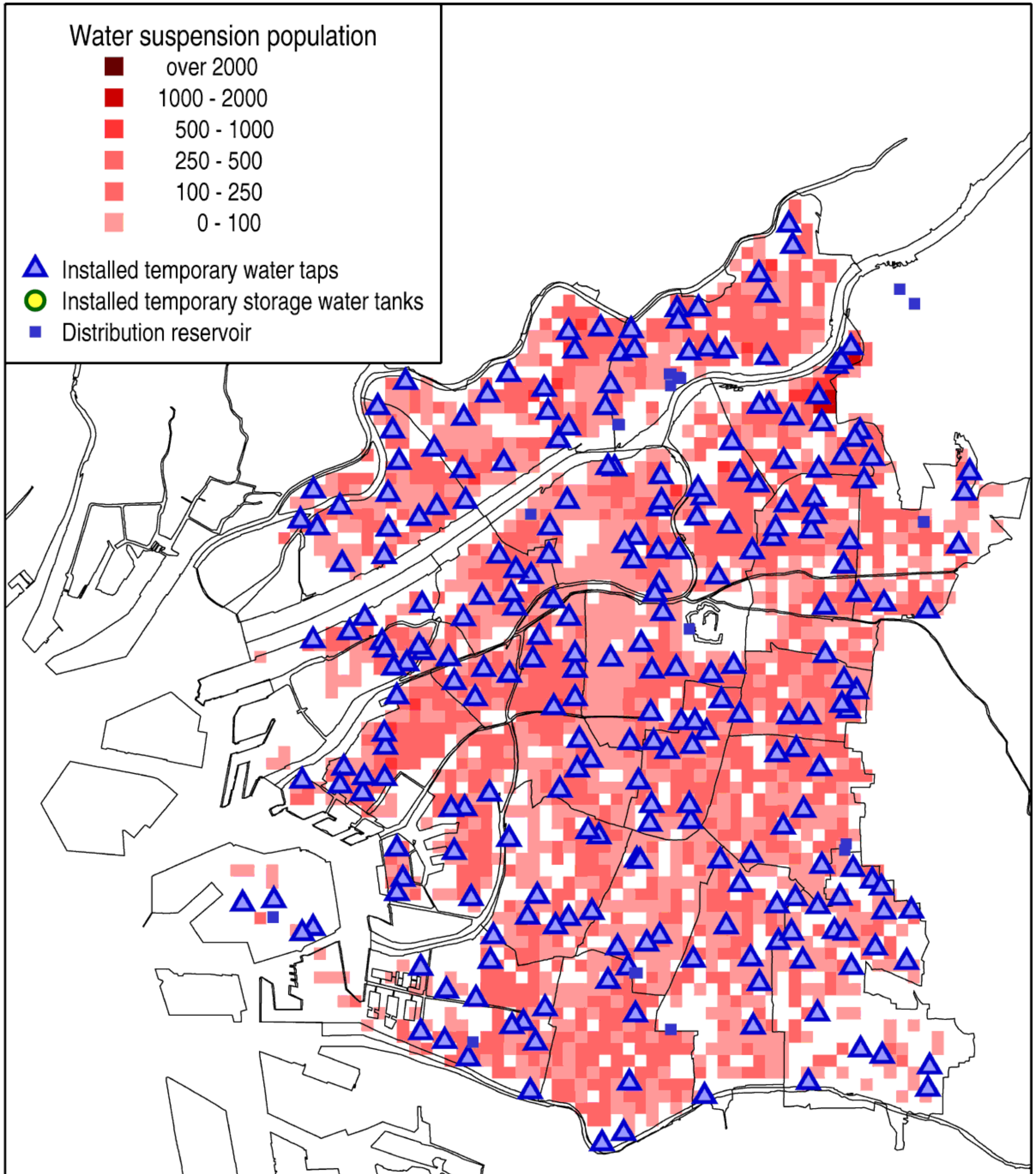
Result : 4



Required water amount 20L/person a day

Water conveying distance for citizens 250m

4th day from earthquake

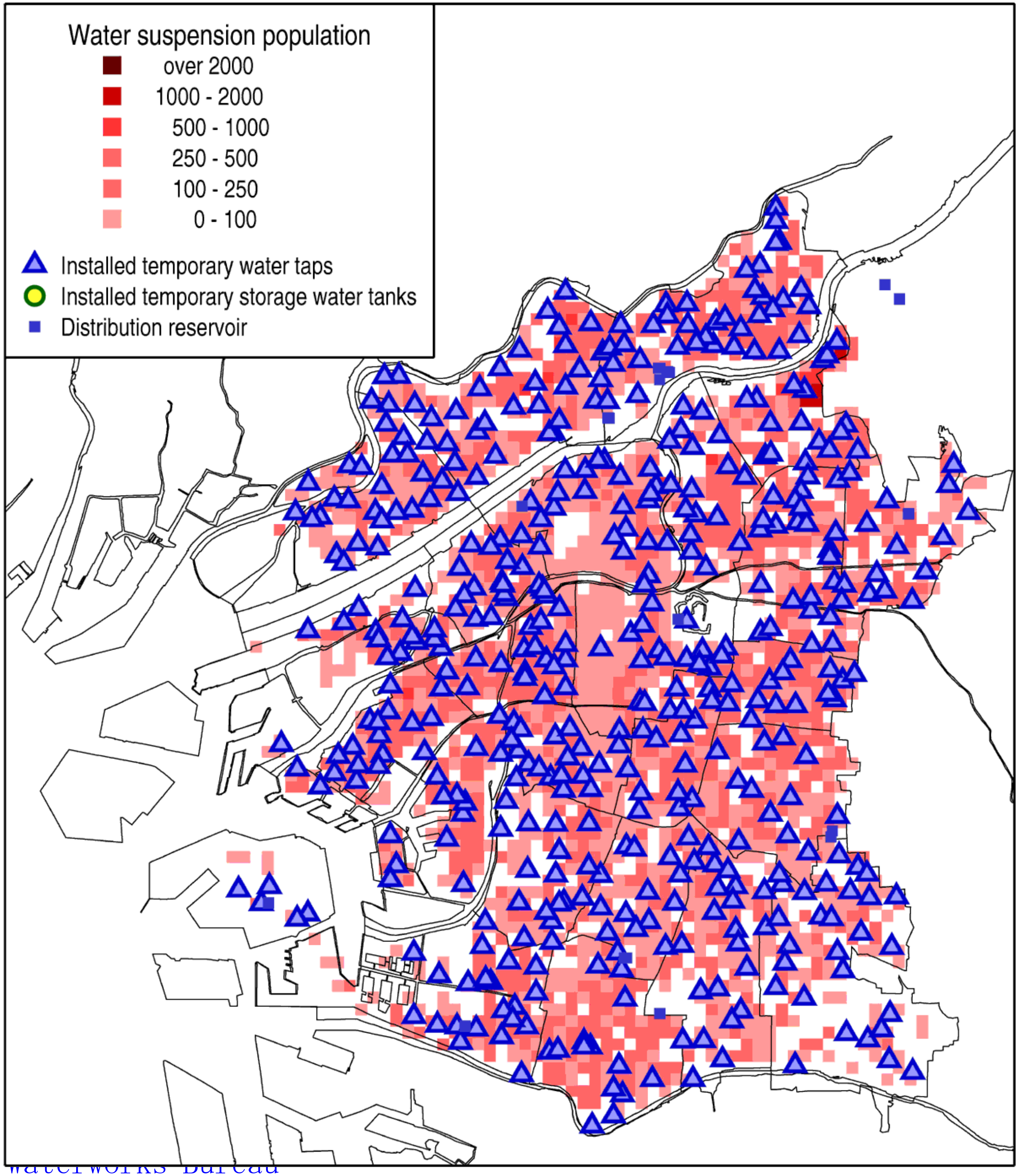


Required water amount 20L/person a day

Water conveying distance for citizens 250m

10th day from earthquake

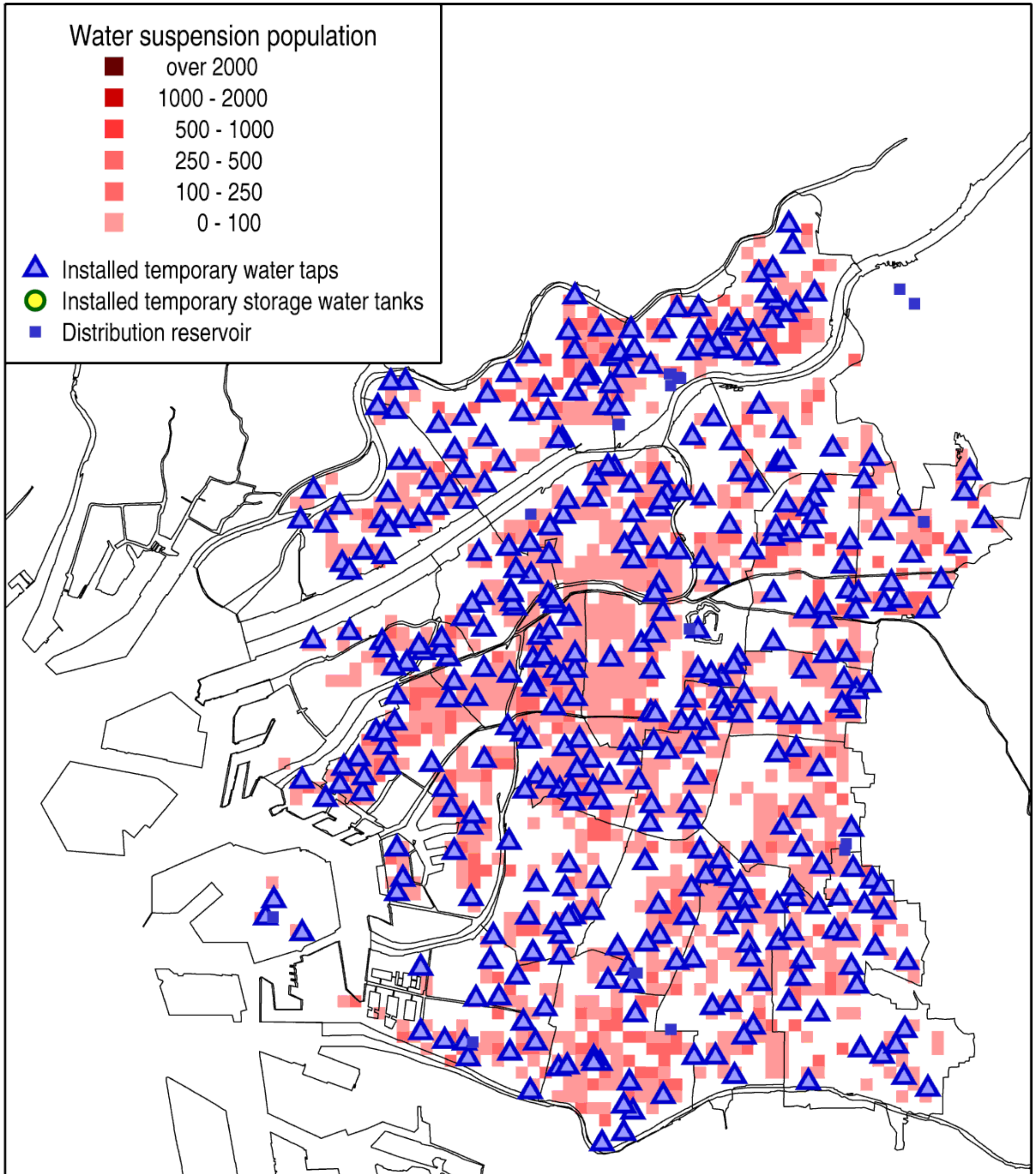
6-10
Result : 6



Required water amount
100L/person a day

Water conveying distance for citizens
100m

11th day from earthquake

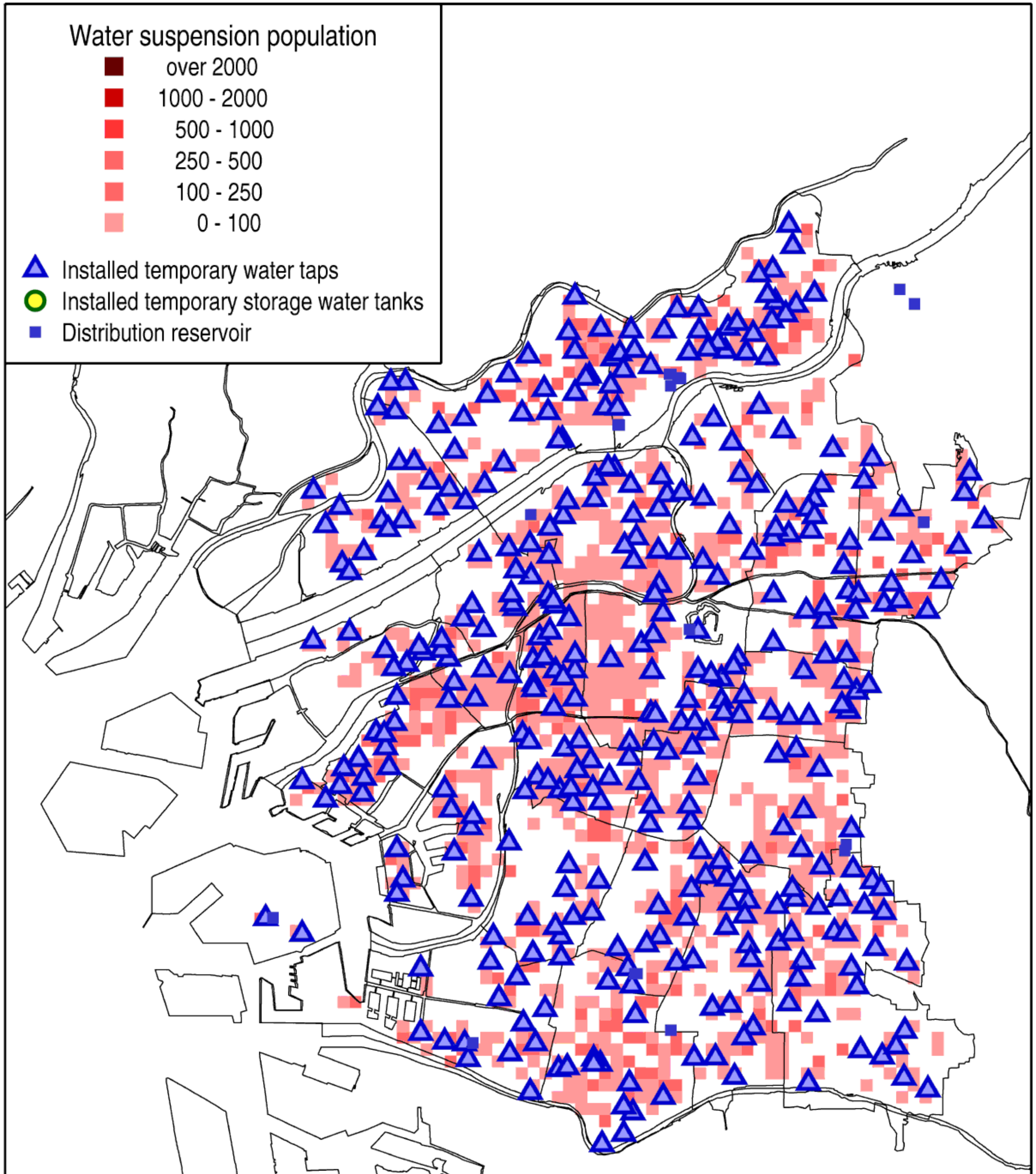


Required water amount 100L/person a day

Water conveying distance for citizens 100m

21th day from earthquake

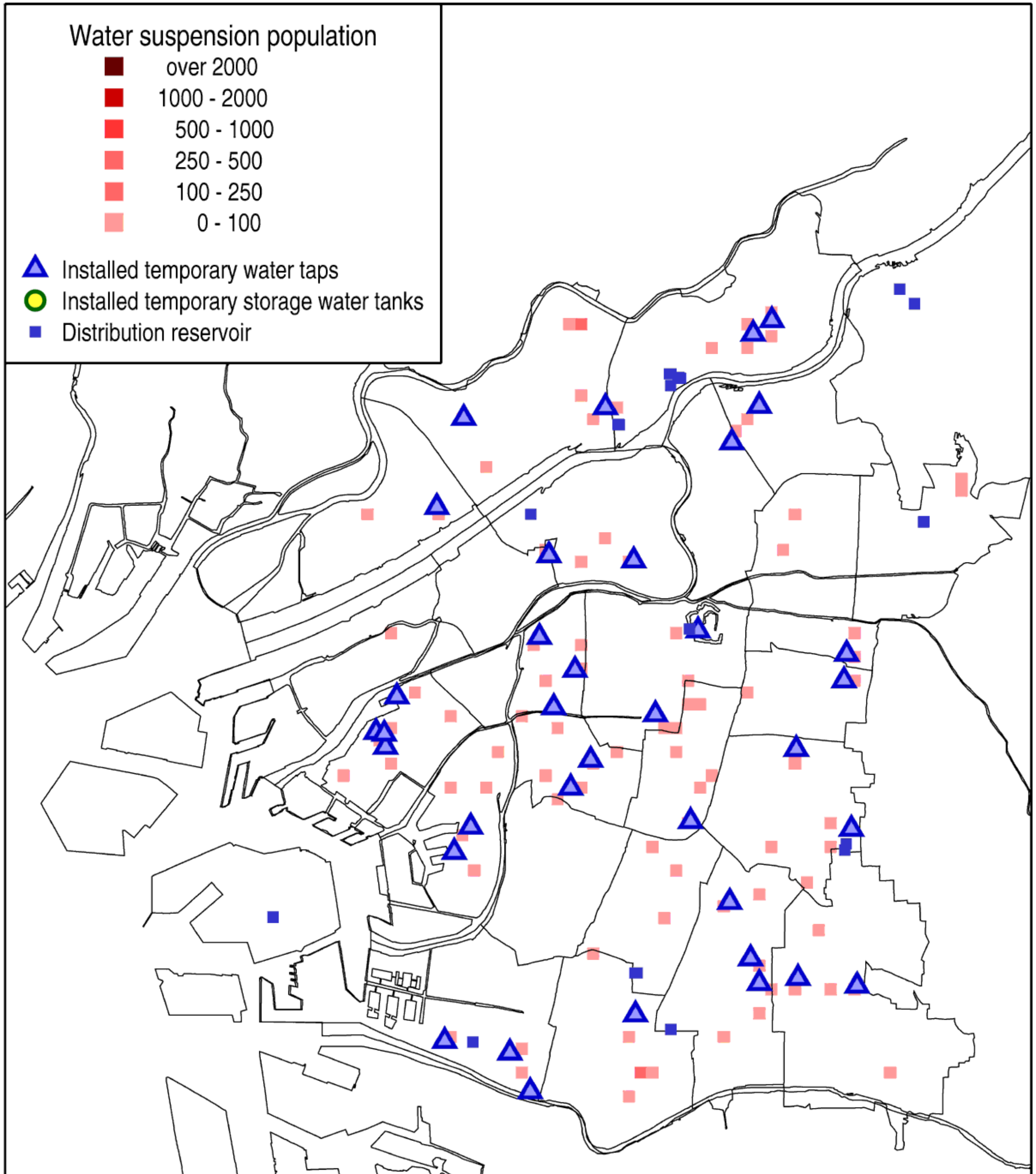
6-12
Result : 8



Required water amount
250L/person a day

Water conveying distance for citizens
100m

22th day from earthquake

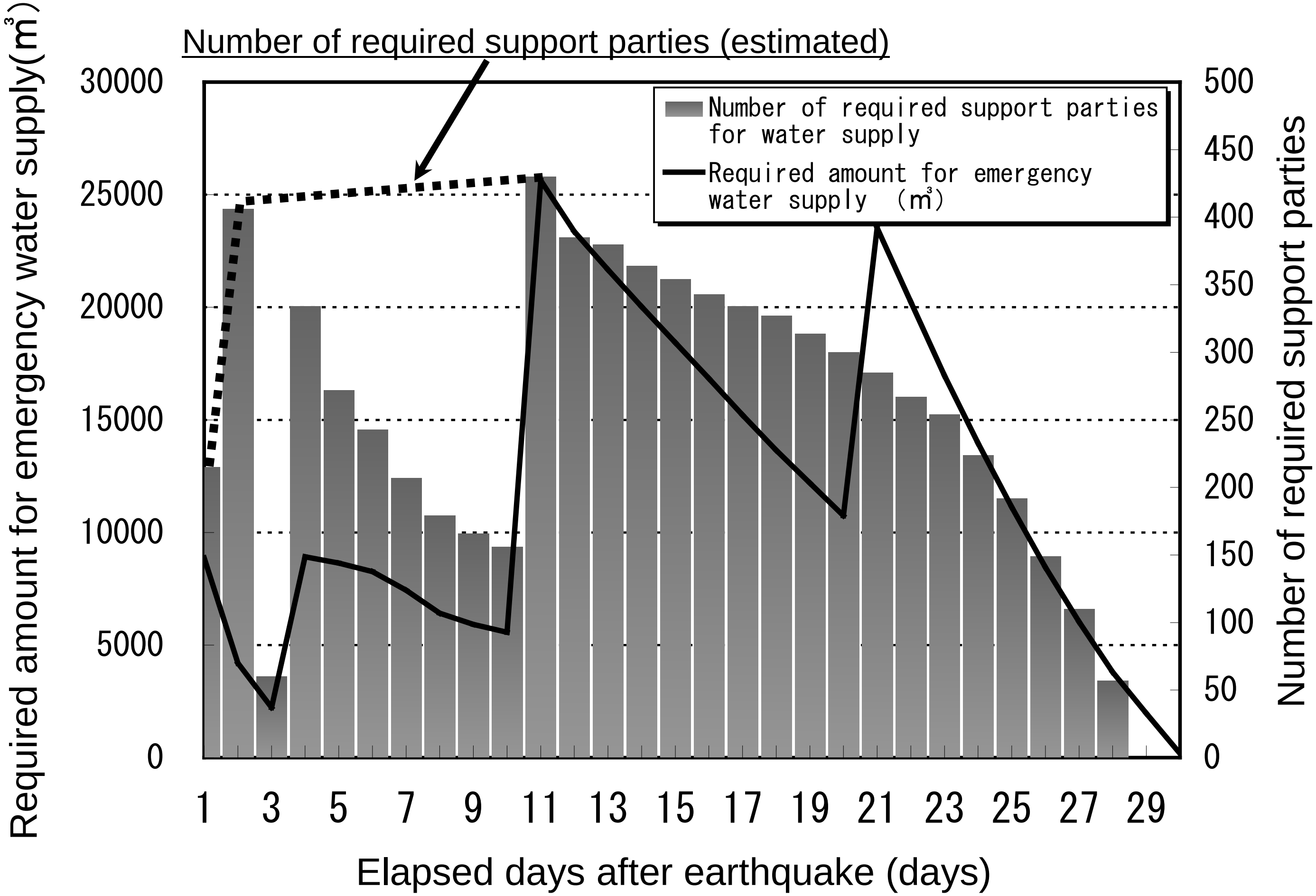


Required water amount 250L/person a day

Water conveying distance for citizens 100m

30th day from earthquake

6-14 Result : Simulation of emergency water supply



- Estimated required amount of emergent water supply according to the restoration progress and target water amount
- Estimated the required number of support parties from the required amount of emergent water supply

7 Conclusion

Developed restoration process simulating method

Estimated the transition of the population in water suspension, the number of centers in service, and the amount of emergent water-supply.
Recognized required number of support parties and equipment necessary for restoration works

Further application of the results

Immediately after the earthquake

- Use as criteria to make swift decisions to request support parties
- Use as grounds to set the restoration target

In early stage after the earthquake

- Use as a guideline to control the restoration progress

Normal times

- Use to evaluate the effectiveness of earthquake prevention project

⇒Try to improve our capability to business continuity