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Stormwater Measures using Rooftop Greenings

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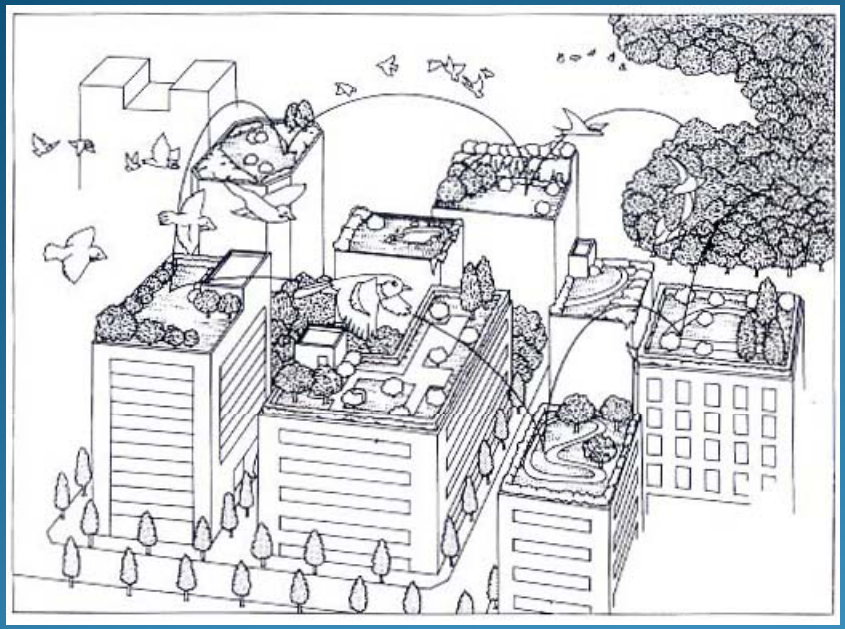
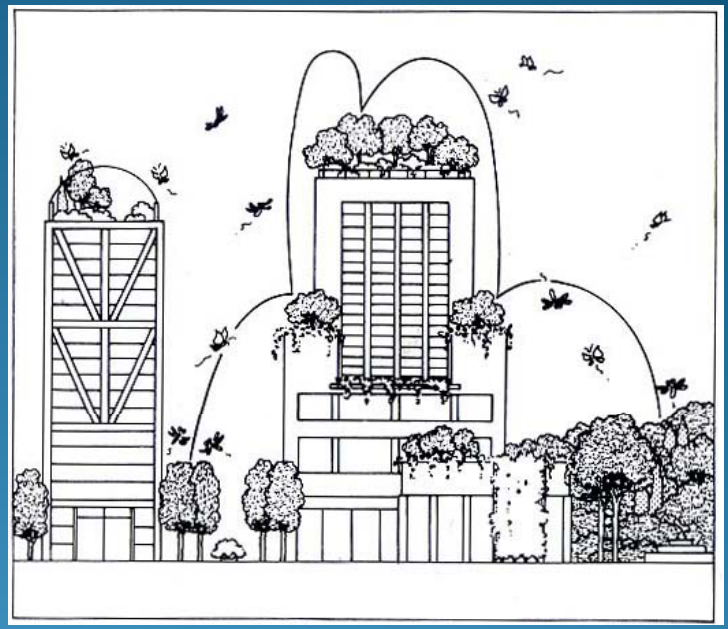
Green Roof Construction Area (m^2) from 2000 to 2007

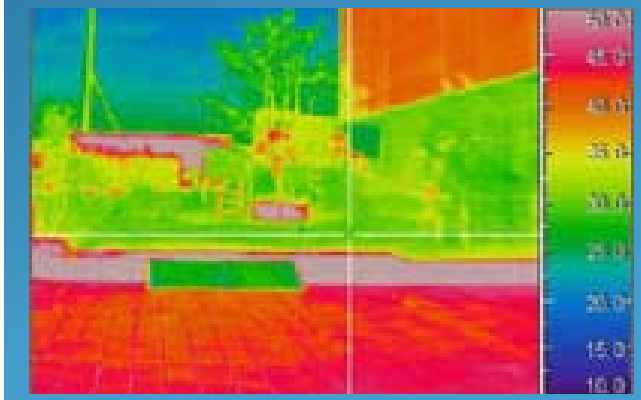
Environmental improvement effect



Horizontal network



Vertical network

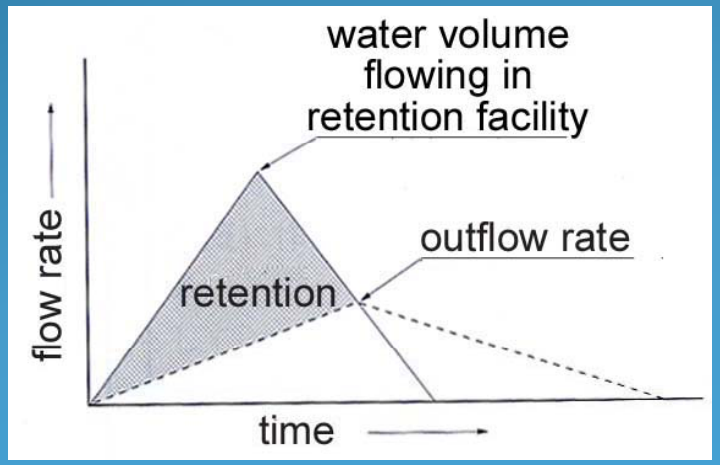


Urban heat island reduce

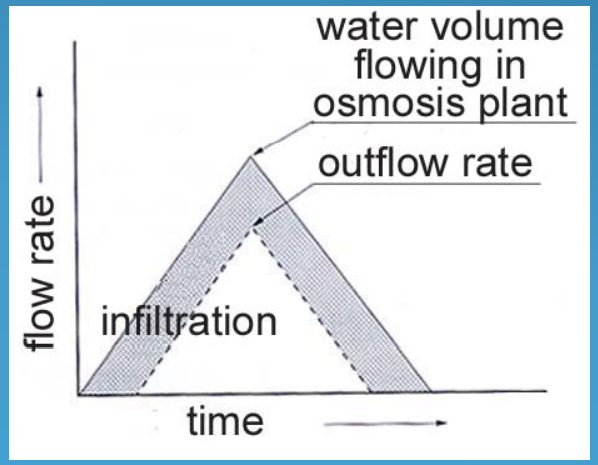
stormwater runoff delay

Comfort, landscape and attracting

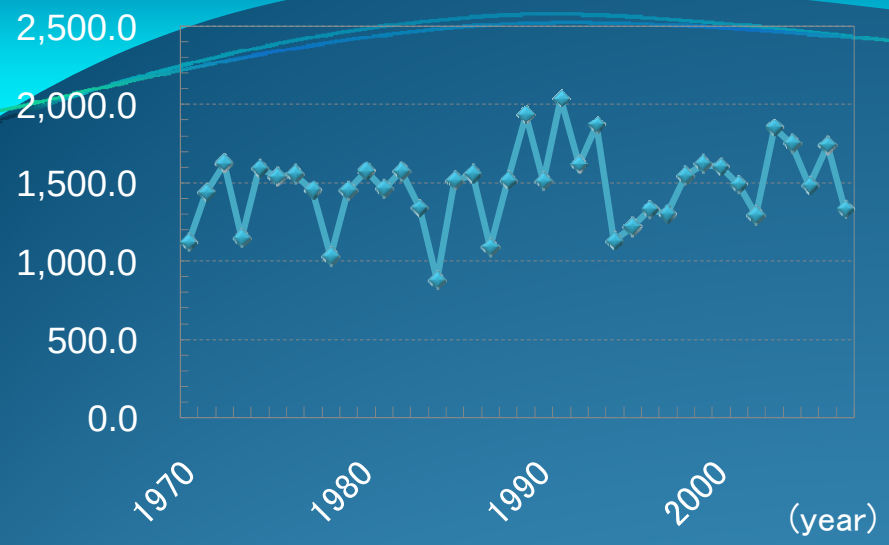
Stormwater runoff delay effect



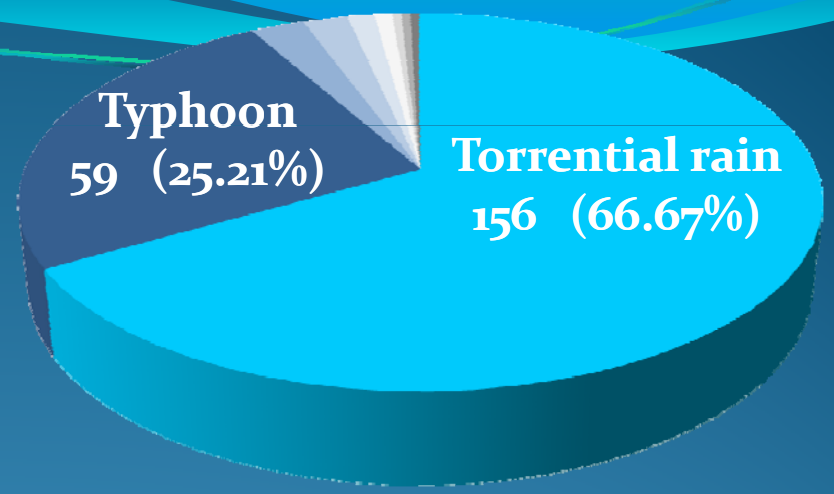
Reservoir-system



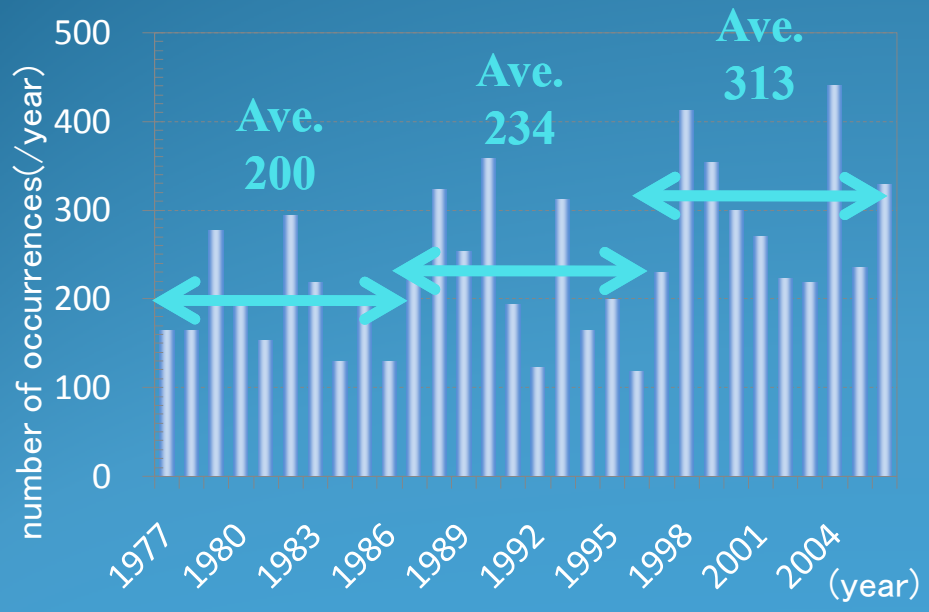
Permeation-system



Rain total (mm)



Source of flood disaster in Tokyo (1974~2006)



Number of rainfall of over 50 mm/hour

Number of rainfall of over 100 mm/hour

Comprehensive flood management measures

River improvement

- Channel improvement
- Construction of retarding basins, floodways

Runoff control

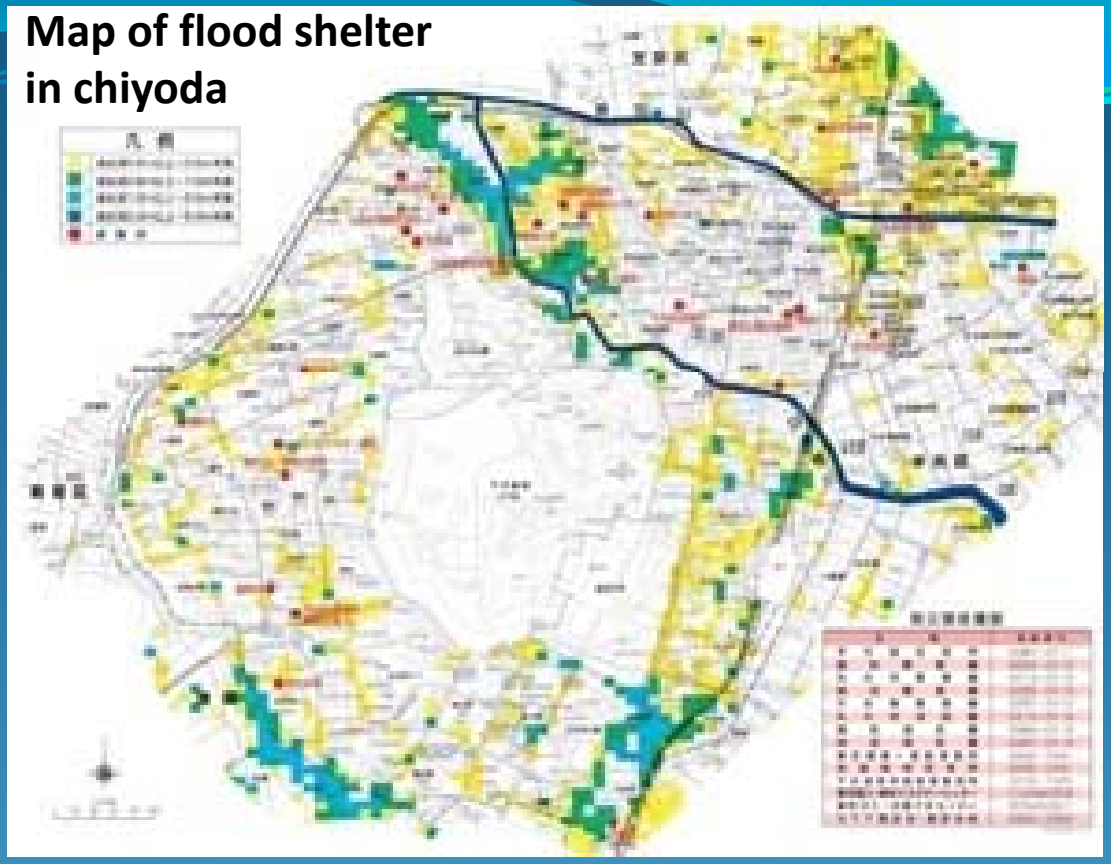
- Maintenance of controlled urbanization districts
- Conservation of nature
- Construction of reservoirs and regulating basins
- Installation of permeable pavements and seepage sumps
- Preservation of urbanization control zones
- Control of landhill
- Promotion of conditions favorable to agricultural activities
- Development of interior drainage facilities
- Construction of storage facilities

Damage Mitigation measures

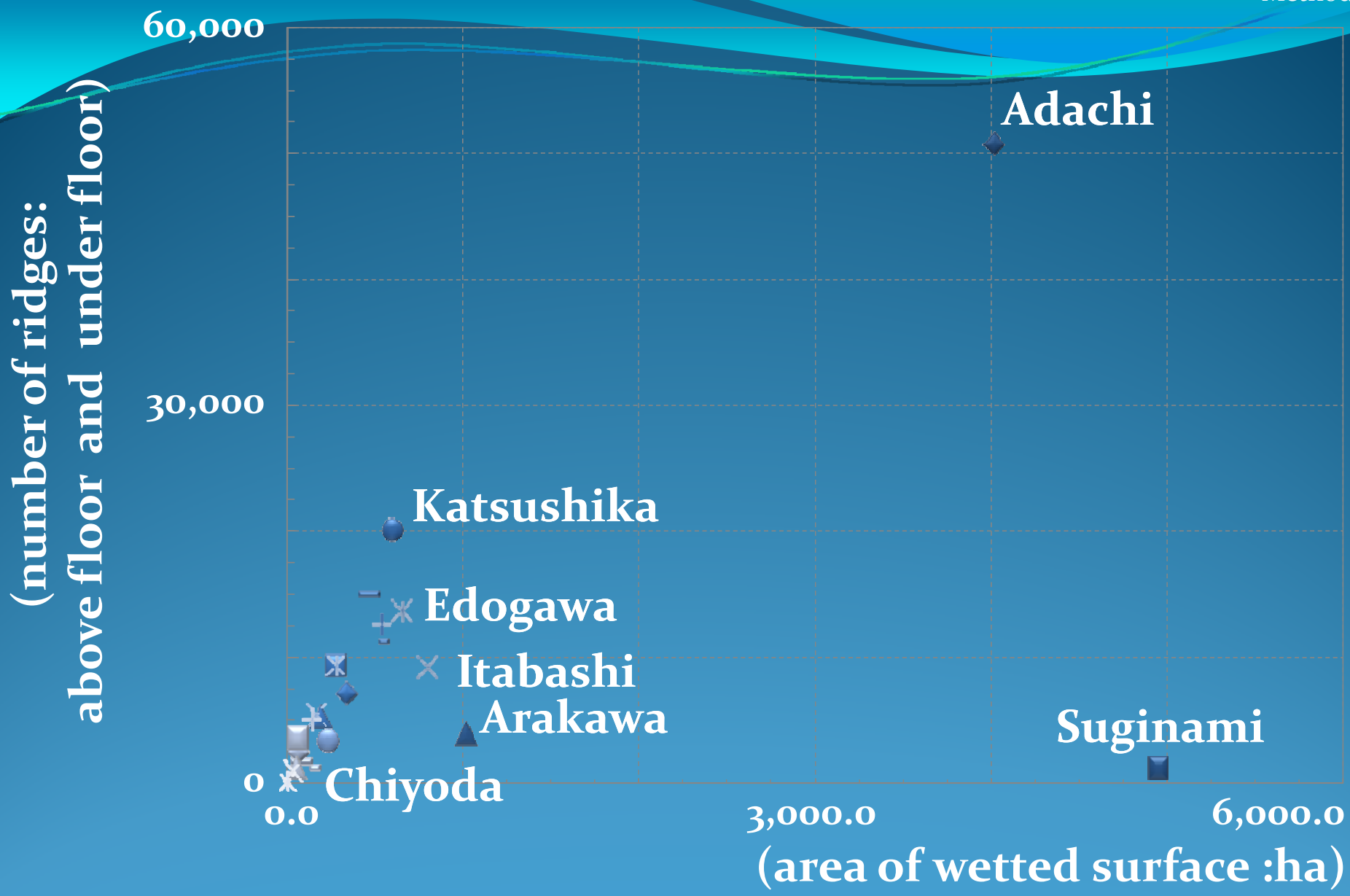
- Encouragement of use of flood-proof buildings
- Establishment of warming and evacuation system
- Augmentation of flood-fighting management system
- Publication of the maps of historical inundation areas and flood-prone areas
- Dissemination of information among local residents

Seepage sumps

Storage facilities → **Rooftop greening**

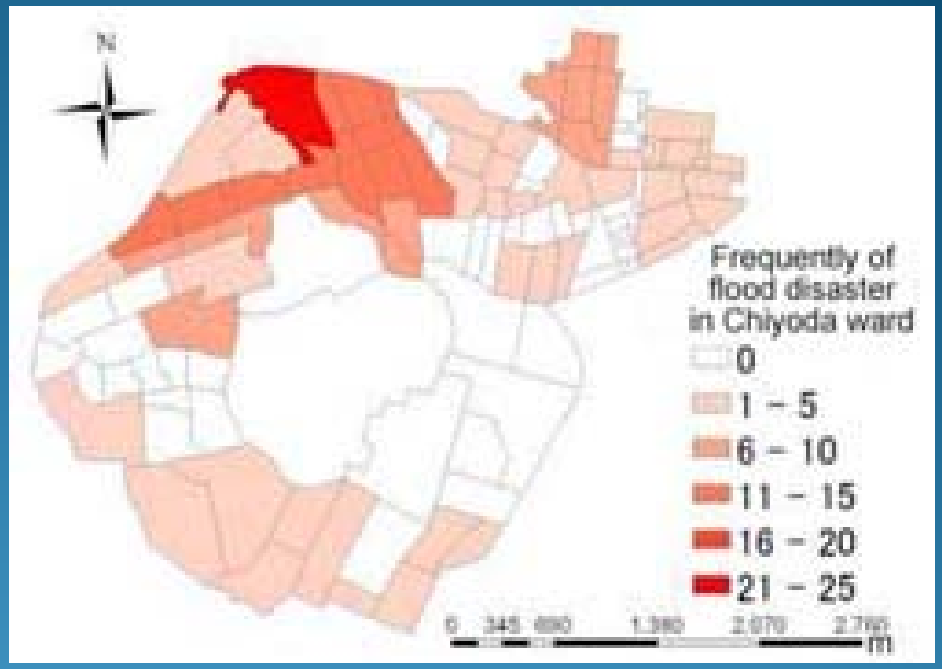


Using some rainfall pattern, analyzing the current situation of stormwater, simulating a stormwater with rooftop greening, we could be made some conditions of land suitability forward creating "rooftop greening suitable area map".



Chiyoda ward, Tokyo, Japan

Aerial photograph (2006)

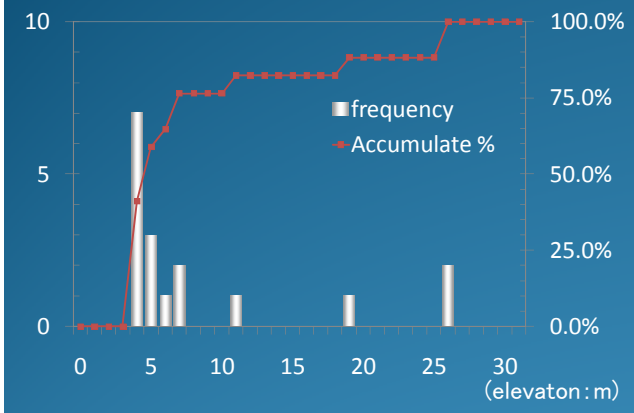


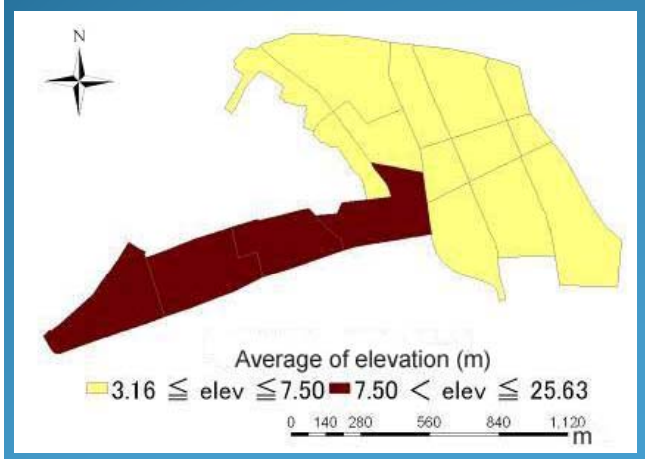
Frequency of flood disaster in Chiyoda ward from 1974 to 2006

Case study areas are 17 blocks;
Iidabashi 1, 2, 3, 4. Misaki -cho1, 2, 3. Kudan-kita 1, 2, 3, 4. Kanda-jimbocho 1, 2, 3. Nishi-kanda 1,2,3.

Surface hydrology

Elevation

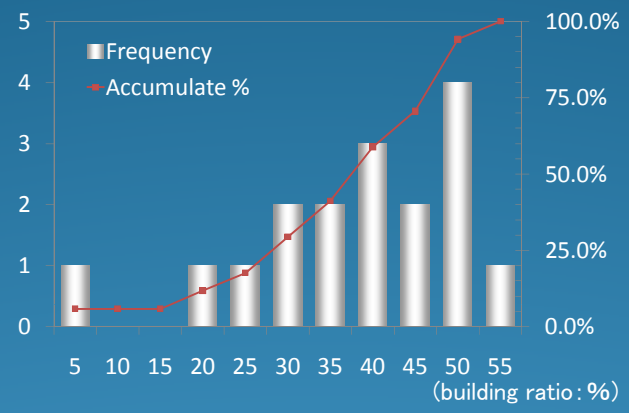


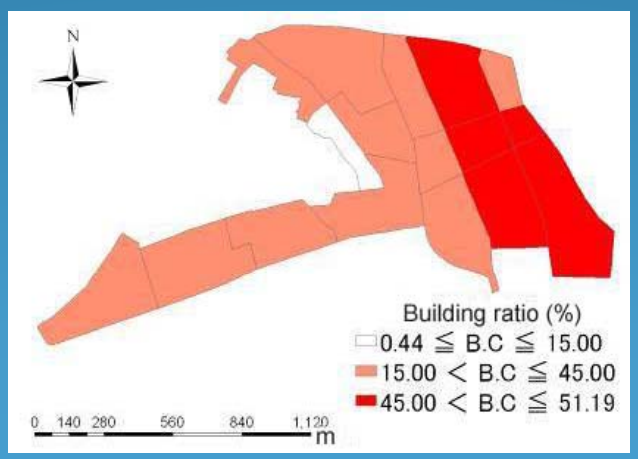


Over 7.5m: high
Under 7.5m: low

Water-holding capability

Building ratio

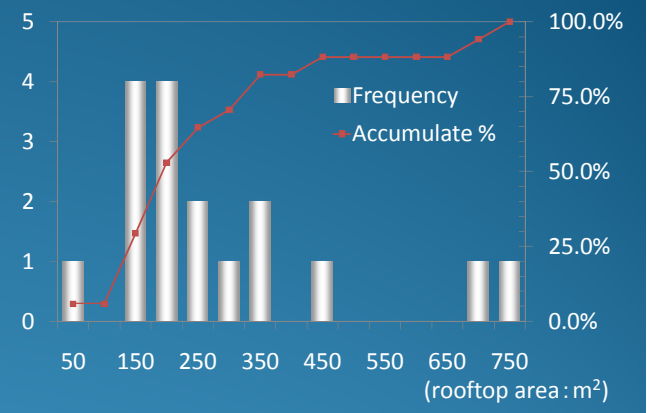


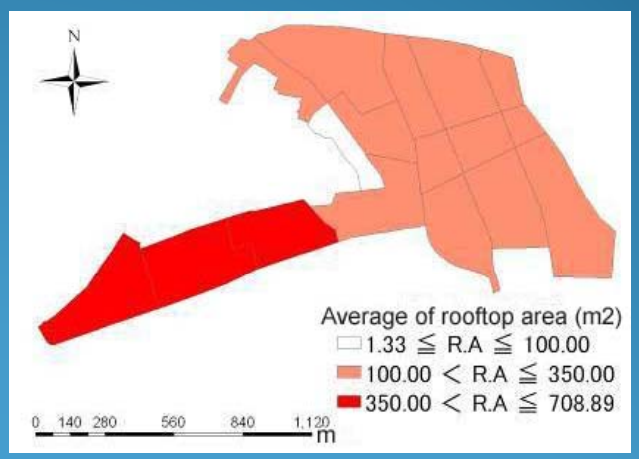


More than 45.00%: high

Rooftop greening area

Rooftop area



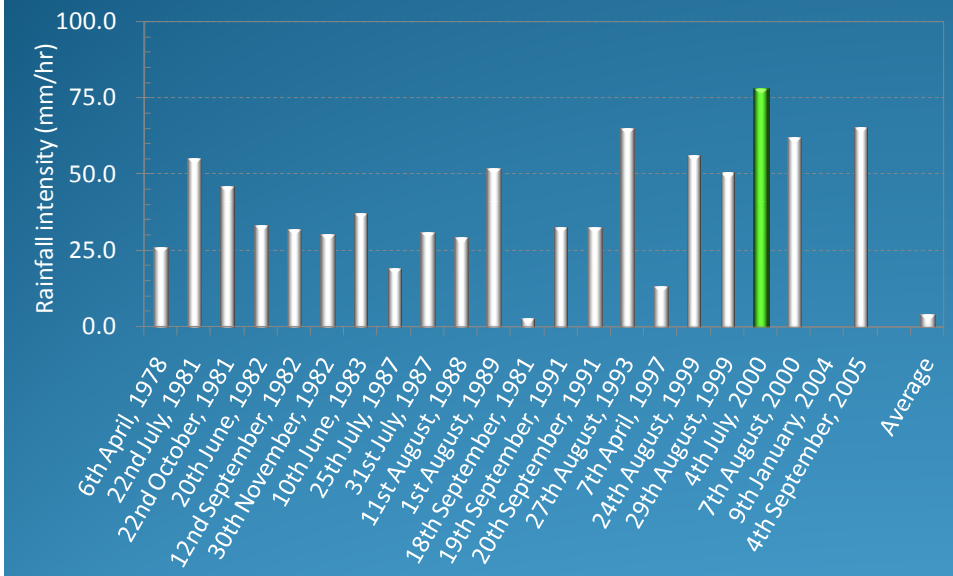


More than 350.00m: large

Torrential rain

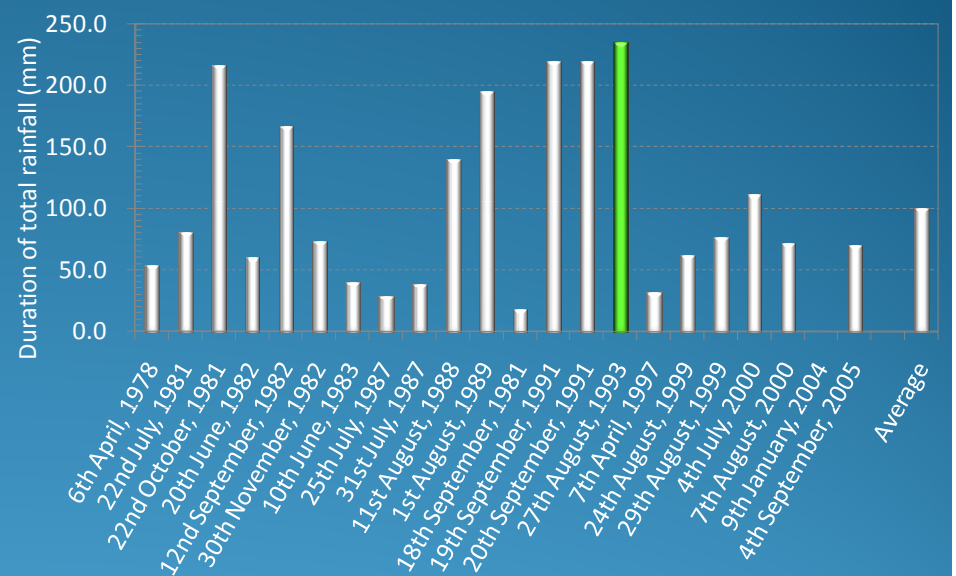
typhoon

Rainfall intensity (mm/hr)



4th July, 2000 78.0mm/hr

Duration of total rainfall (mm/day)

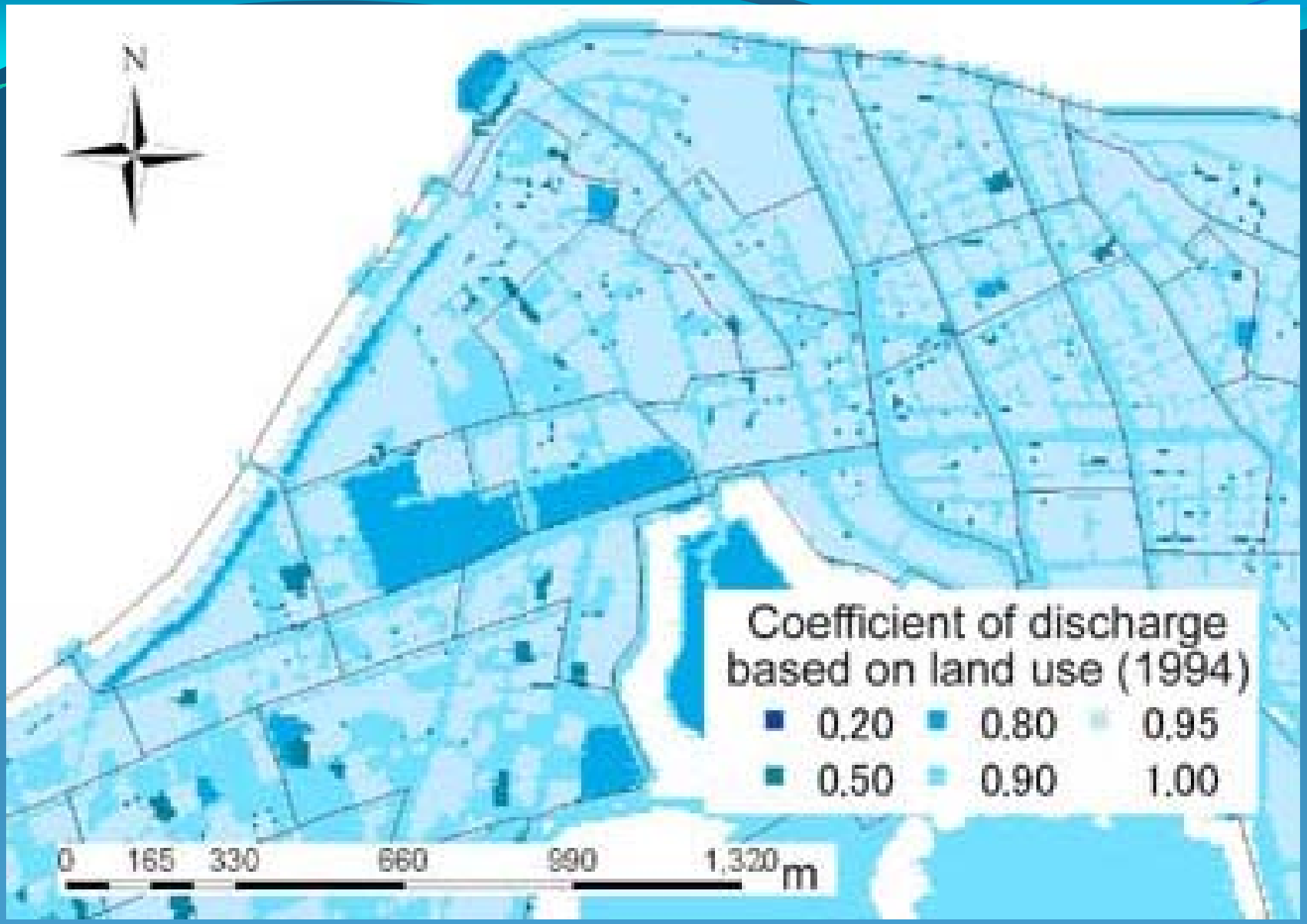


27th August, 1993 234.5mm/day

Average of water inundation disaster	**Rainy season**
Rain-intensity	**4.2 mm/hr**
Duration of total rainfall	**100.4 mm/day**

Coefficient of discharge

0.20	0.50	0.80	0.90	0.95	1.00
Rice field	Parks and greenery spaces	Parks and greenery spaces	Road	Other community-public facilities	Rivers and lakes
Dry field	Under developed land		Mid-to-high-rise housing area	Commercial-business area	
Other agricultural land	Open spaces		Density low-rise apartment housing area	Industrial area	
Mountain district			Low-rise apartment housing area		
Wilderness					



Infiltration- impermeability distribution map

Coefficient of discharge	Efflux start time
0.80	12’37’’

(Murayama et Koshimizu, 1997)

Commercial –business area

Other community-public facilities

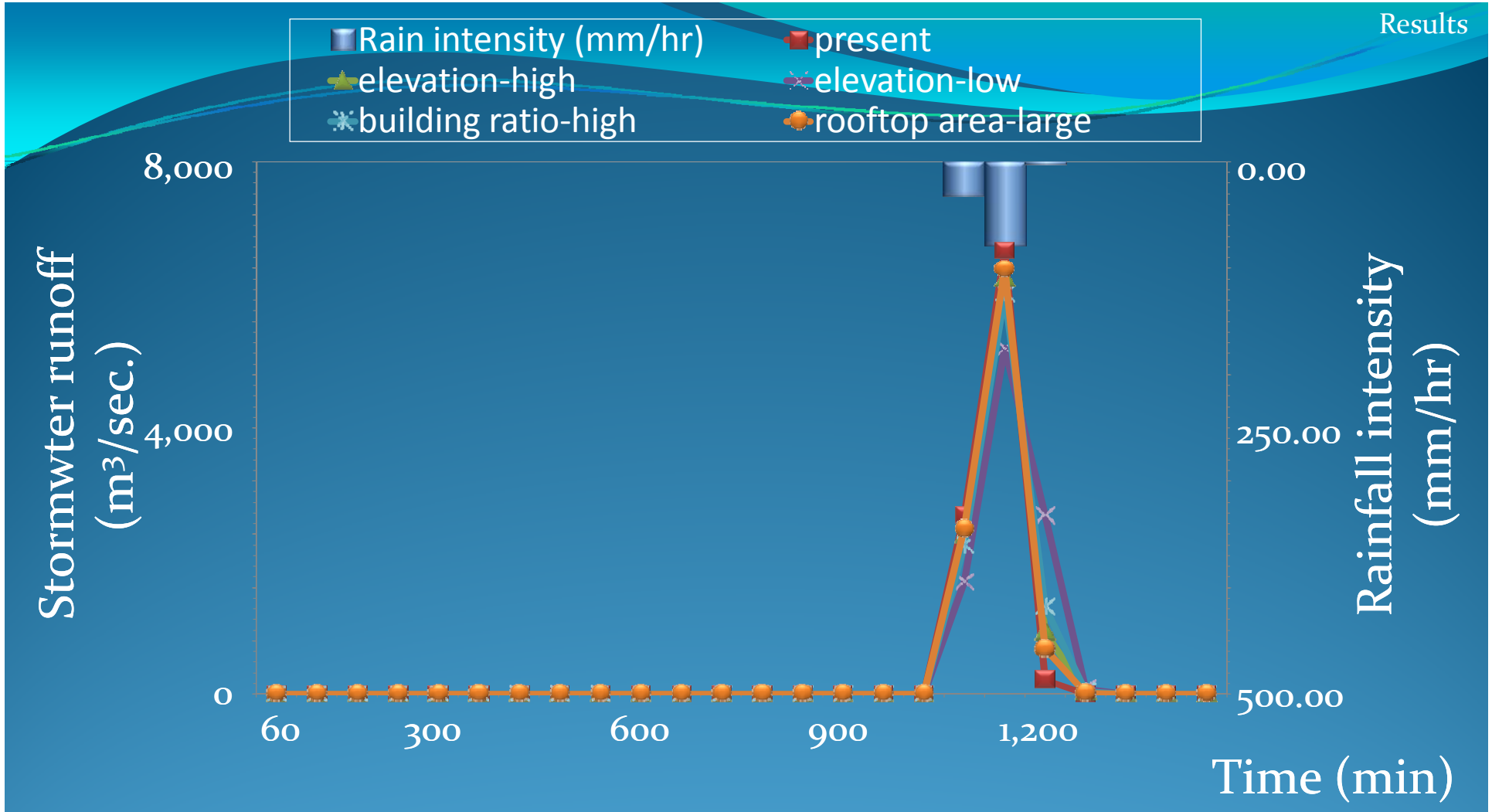
0.95 → 0.80

Stormwater runoff $$Q = (C*I*A)/3600 \quad \cdots \quad (1)$$

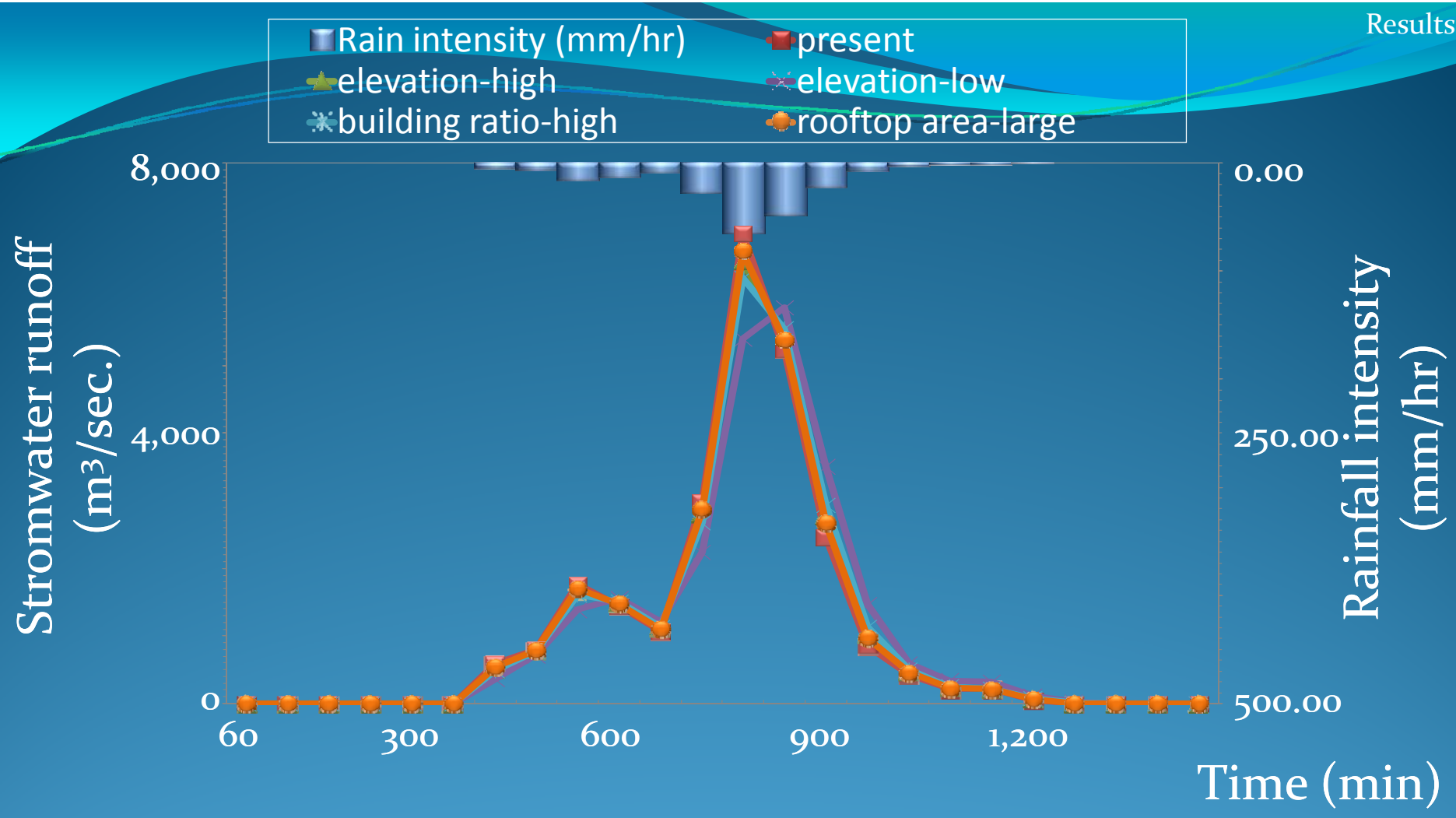
Flood tide effect $$\Delta Q = Q_p - Q_c \quad \cdots \quad (2)$$

Flood tide lowering ratio $$p = (Q_p - Q_c)/Q_p \quad \cdots \quad (3)$$

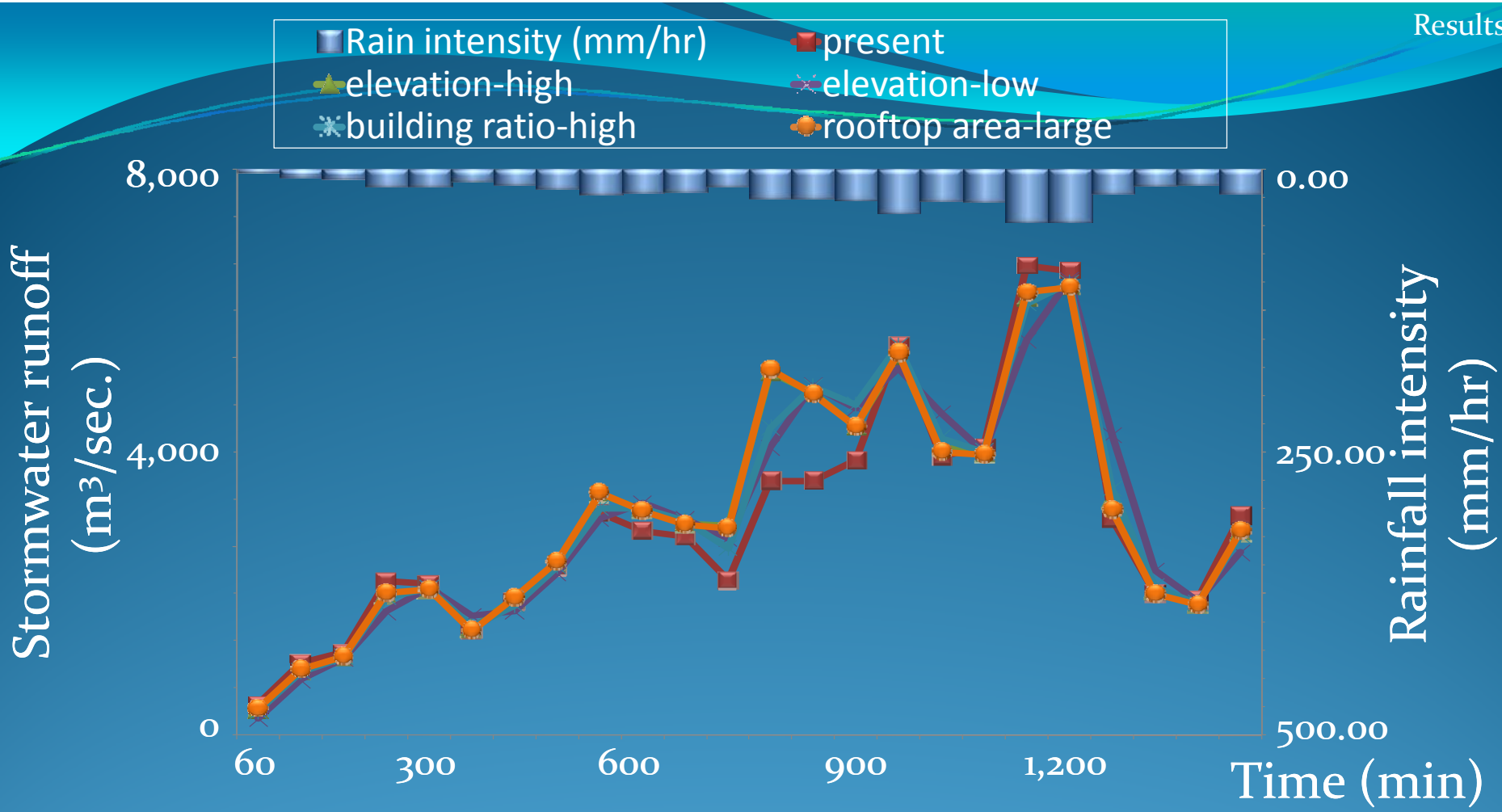
- Q Stormwater runoff (m³/sec.)
- C Coefficient of discharge
- I Average of rain intensity in arrival time t (mm/hr)
- A Block area (ha)
- ΔQ Flood tide effect (m³/sec.)
- Q_p Present stormwater runoff (m³/sec.)
- Q_c Rooftop greening stormwater runoff (m³/sec.)
- P Flood tide lowering ratio



		Elevation high	Elevation low	Building ratio	Rooftop area	time
Q (m³/min.)	8,331	7,805	6,503	7,519	7,988	1,140
⊿*Q* (m3/min.)		526.0	1,828	811.8	343.1	1,140
Rainfall finished *p*		-3.28	-11.57	-5.136	-2.171	



		Elevation high	Elevation low	Building ratio	Rooftop area	time
Q (m³/min.)	6,942	6,524	5,395	6,297	6,670	780
⊿*Q* (m3/min.)		417.7	1,547	644.8	272.5	780
Max *p*		0.120	0.388	0.166	0.074	420



		Elevation high	Elevation low	Building ratio	Rooftop area	time
Q (m³/min.)	995.3	924.8	837.8	914.5	938.6	1,140
⊿*Q* (m3/min.)		70.45	157.5	80.71	56.64	1,140
Time of occurrence *p*		---	~240, 420~540	---	300~360	

Torrential rain

Stormwater runoff delay effect was contributed in maximum rain intensity.
Due to several spatial characteristics of rooftop greening constructing conditions, the stormwater runoff was different by rainfall finished.

Typhoon

Stormwater runoff delay effect had the greatest in maximum rain intensity.
The effect was contributed at the beginning of rainfall time.

Rainy period

Due to several spatial characteristics of rooftop greening constructing conditions, the flood tide effect and the flood tide lowering ratio showed different trends.

As results of the stormwater runoff simulation based on the several spatial characteristics, such as elevation, building ratio, and rooftop area, it was showed the rooftop greening has the stormwater runoff delay effect.

When a torrential rain, rooftop greening have a stormwater runoff delay effect at the beginning of it.

Examination of the rain intensity and the rainfall pattern to be able to expect stormwater runoff delay effect.

Setting of the coefficient of discharge and the efflux start time by the constructing rooftop greening.

Grasp the sewerage maintenance condition, the watershed features.

Forward creating "rooftop greening suitable area map", it is necessary to the quantification of stormawater runoff delay effect by rooftop greening.

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