French – Japanese – Dutch
workshop on impacts of climate change on hydrology

Adaptation Strategy for Climate Change in Japan

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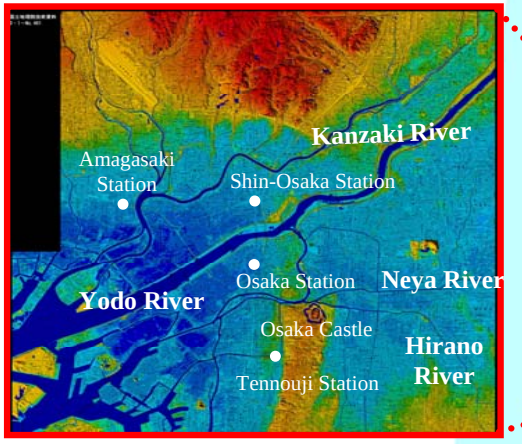
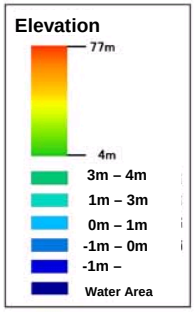
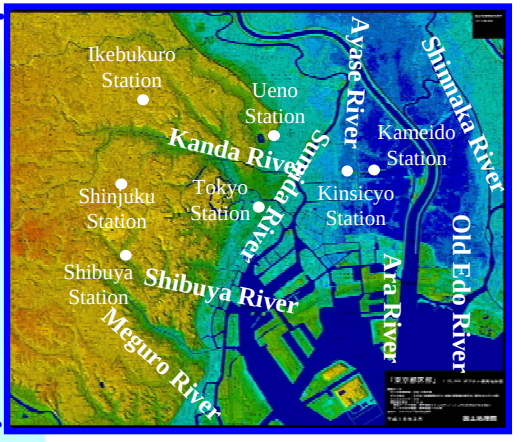
Japan is vulnerable to climate change.

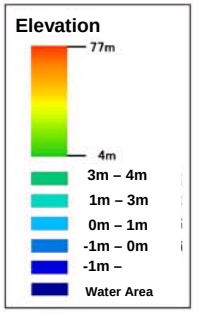
Kinki Region

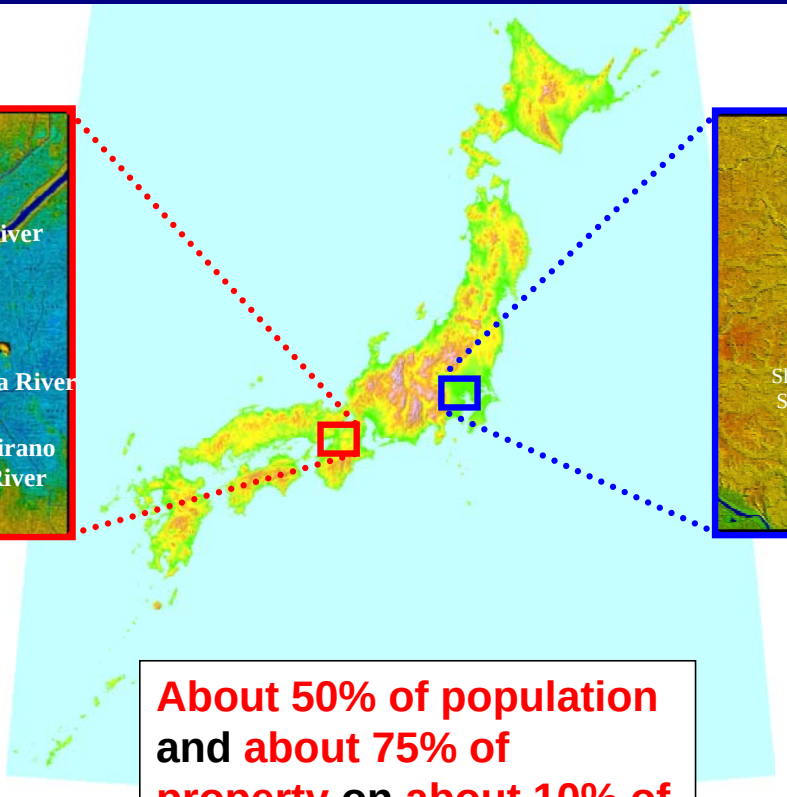




Kanto Region



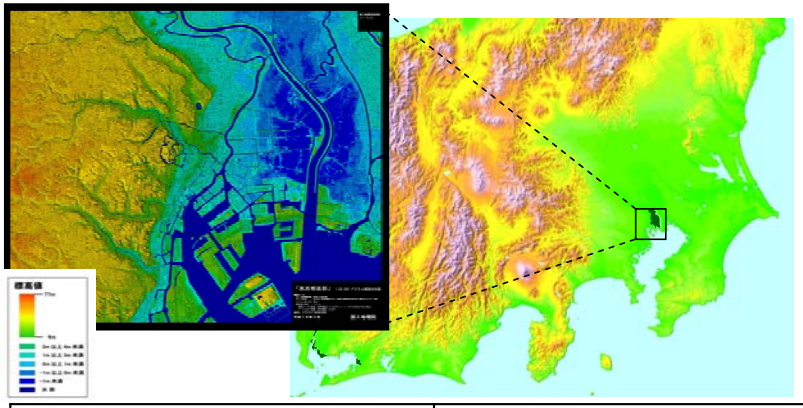


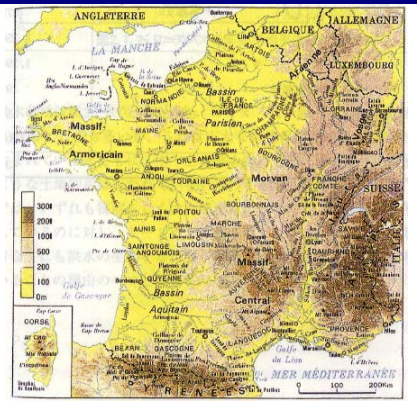


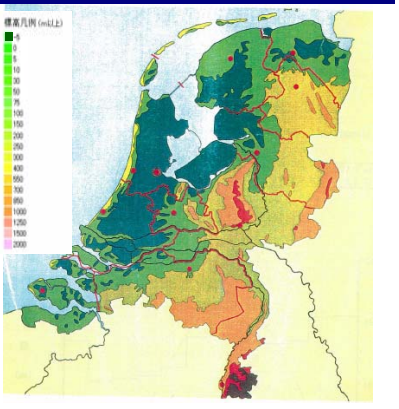
About 50% of population and about 75% of property on about 10% of land lower than water levels in rivers during flooding

Japan, France and the Netherlands

1. Present conditions in Japan







		Japan	France	The Netherlands
Geographical characteristics		・Area：**378,000km2** ・Many short steep rivers. ・Sediment problems because of poor soil ・Flood plain area is located by alluvial fan and riverside	・Area：**547,000km2** ・Almost nation land is Gently rolling plain and hill ・South Pyrenees and East Alps are precipitous mountains	・Area：**42,000km2** ・Rhine River, Maas River, Schelde River as mild slope international river ・Delta and low area
Profile of represent ative river	Name of River	**Tone River**	**Seine River**	**Rhine River**
	Basin Area	**About 17,000km2**	About 78,000km2	**About 185,000km2**
	length of river	**322km**	776km	**1,320km**
	Average bed slope	**About 1/175**	About 1/1,650	**About 1/2,600**
	largest flow discharge	**17,000m3/s(1947)**	**2,400m3/s (1910)**	**13,000m3/s (1926)**
Climate characteristics	annual mean rainfall	**1,718mm**	About 1,000mm	**About 800mm**
	100 year daily precipitation	**376mm (Tokyo)**	About 79.4mm (Montsouris)	**80mm (de Valdo)**
	100 year hourly precipitation	**94mm (Tokyo)**	About 47.4mm (Montsouris)	**40mm (de Valdo)**

Mechanism of global warming and climate change (impacts on water-related disasters)

Large volumes of greenhouse gas emissions cause CO_2 concentration in the air to rise and increase heat absorption, resulting in temperature rise. Thus, global warming occurs.

- Melting of glaciers, ice caps and ice sheets
- Thermal expansion of sea water
- Change in evapotranspiration
- Change in snow accumulation condition

- Sea level rise (Maximum rise: 59 cm)
- More intense typhoons
- Increase of precipitation by a factor of 1.1 to 1.3*
- More frequent heavy rains and droughts
- Earlier snow melt and reduction of discharge

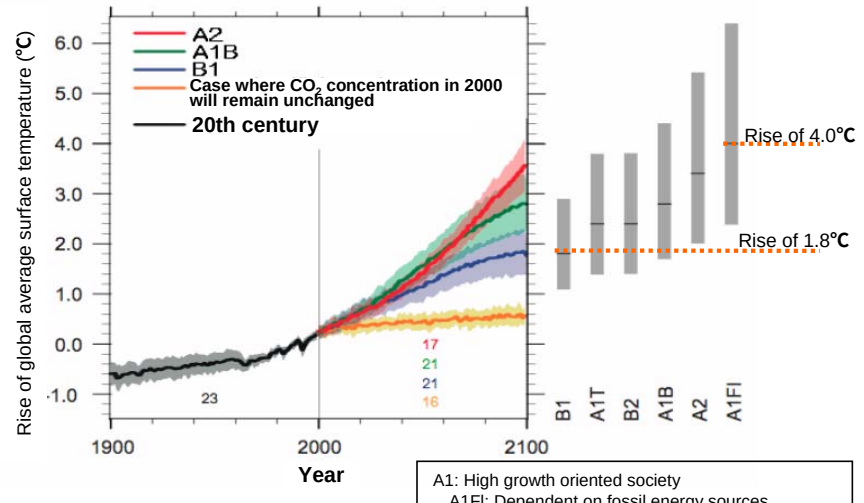
- Increase of river flow rate
- Change in water use pattern

- More frequent high tides and coastal erosions
- More frequent floods
- More serious debris flow
- Higher risk of drought

Rises of temperature and sea level

-Temperature is expected to rise by about 0.2℃ per decade in the next 20 years.
-Global average surface temperature is expected to rise by 1.8 to 4.0℃ in 100 years' time from now.
-Global average sea level is expected to rise by 18 to 59 cm in 100 years' time from now.
-Global warming and sea level rise will continue over several centuries even if green-house gas emissions are controlled.

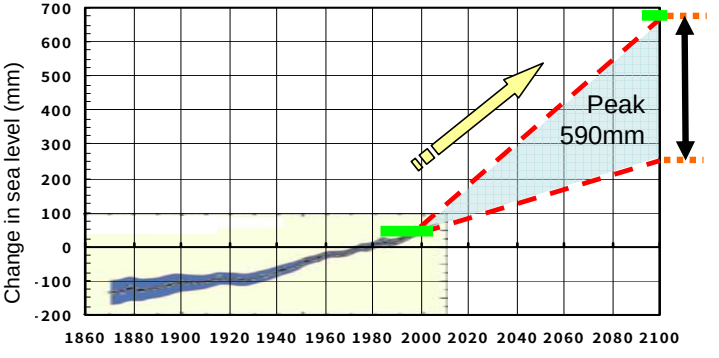
• Average temperature



A1: High growth oriented society
A1FI: Dependent on fossil energy sources
A1T: Dependent on non-fossil energy sources
A1B: Emphasis on the balance among various energy sources
A2: Multipolarized society
B1: Sustainable growth oriented society
B2: Emphasis on regional initiatives

Source:
IPCC AR4 WG1 (Working Group 1) Summary for Policymakers (Japan Meteorological Agency)
-Solid lines indicate rises of global average surface temperature in each scenario identified using multiple models.
-Shaded areas indicate the range of standard deviations of average annual temperature for each model.

• Average sea level



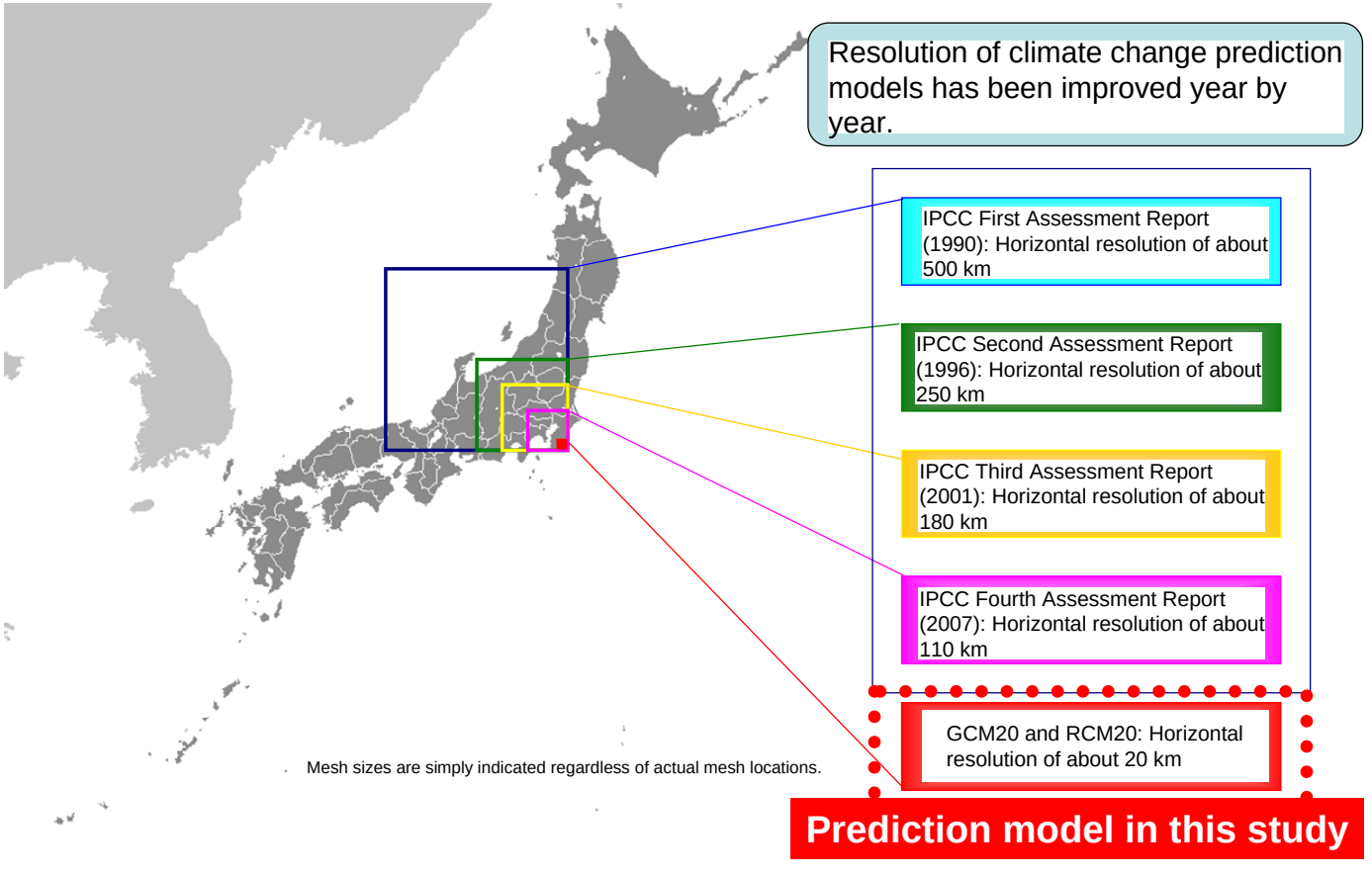
Source: Data prepared by the River Bureau based on the IPCC AR4 WG1 Report

・Rises of average temperature and sea level at the end of the 21st century

	Society achieving both global environmental protection and economic development	Society achieving high economic growth dependent on fossil energy sources
Temperature rise	About 1.8℃ (from 1.1℃ to 2.9℃)	About 4.0℃ (from 2.4℃ to 6.4℃)
Sea level rise	Sea level rise	26～59cm

Source: IPCC AR4 WG1 Report

Resolution of climate change prediction models



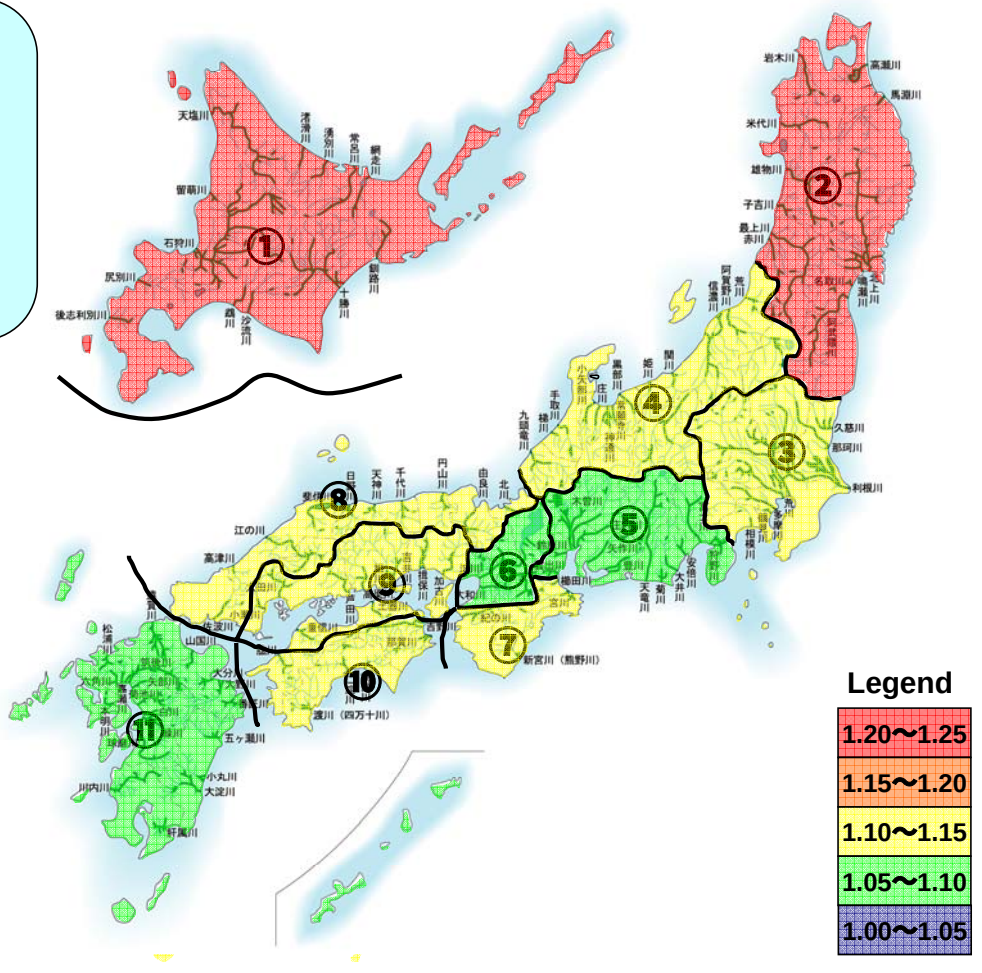
Estimation of increased rainfall in region

Future rainfall amounts were projected as a median value in each region of

$$\frac{\text{Average rainfall in 2080-2099 period}}{\text{Average rainfall in 1979-1998 period}}$$

The above equation was obtained based on the maximum daily precipitation in the year at each survey point identified in GCM20 (A1B scenario).

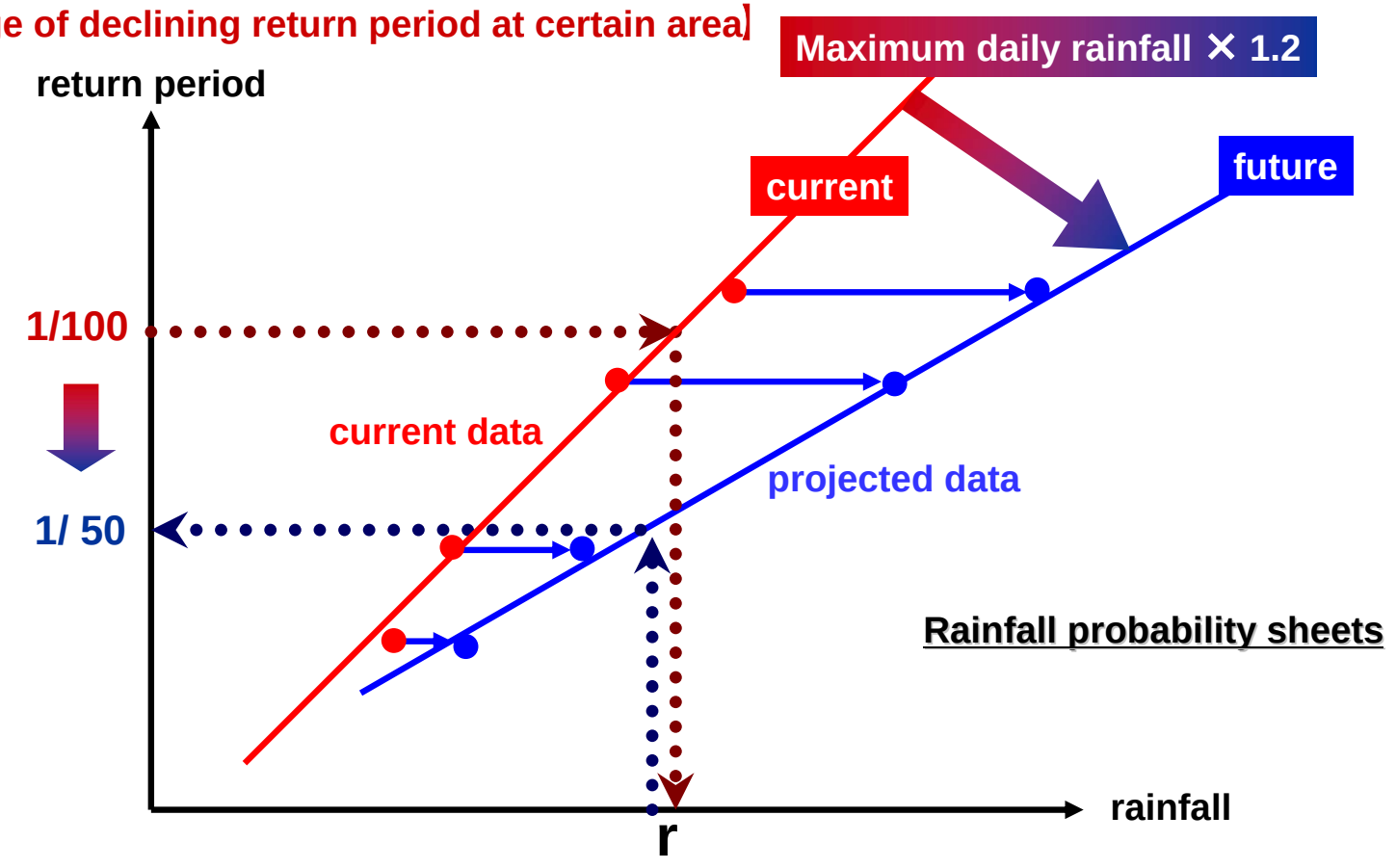
①	Hokkaido	1.24
②	Tohoku	1.22
③	Kanto	1.11
④	Hokuriku	1.14
⑤	Chubu	1.06
⑥	Kinki	1.07
⑦	Southern Kii	1.13
⑧	San-in	1.11
⑨	Setouchi	1.10
⑩	Southern Shikoku	1.11
⑪	Kyushu	1.07



Declining return period by increasing rainfall

Return period of flood is declining by increasing rainfall in the future. Therefore declining future flood safety level is estimated.

【Image of declining return period at certain area】

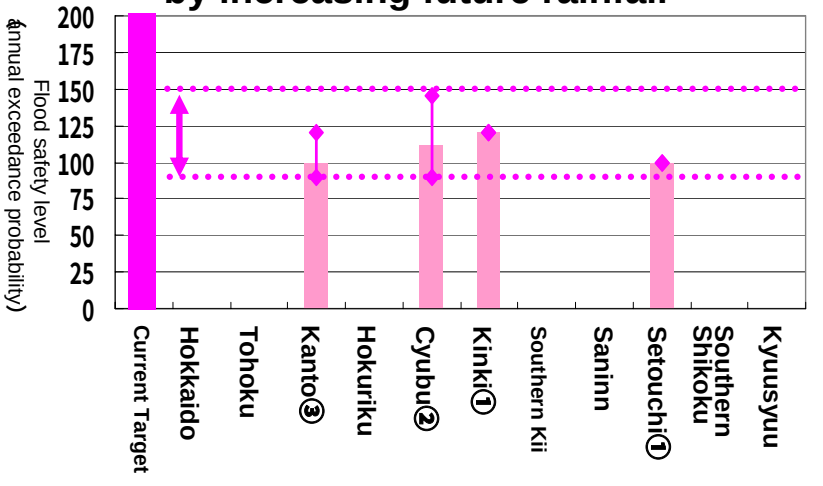


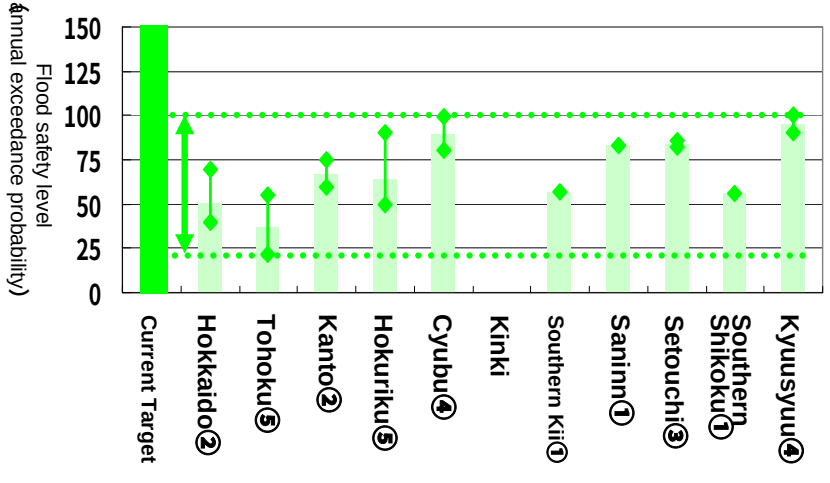
Declining the degree of safety level

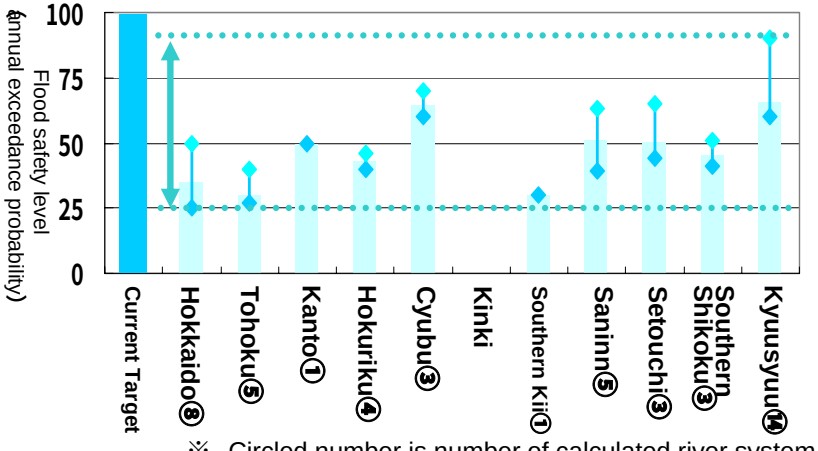
Impact for flood safety level by changing rainfall after 100 years

Region	1/200 (CurrentTarget)		1/150 (CurrentTarget)		1/100 (CurrentTarget)	
	Future flood safety level (annual exceedance probability)					
		Number of river system		Number of river system		Number of river system
Hokkaido	–	–	1/40～1/70	2	1/25～1/50	8
Tohoku	–	–	1/22～1/55	5	1/27～1/40	5
Kanto	1/90～1/120	3	1/60～1/75	2	1/50	1
Hokuriku	–	–	1/50～1/90	5	1/40～1/46	4
Cyubu	1/90～1/145	2	1/80～1/99	4	1/60～1/70	3
Kinki	1/120	1	–	–	–	–
Southern Kii	–	–	1/57	1	1/30	1
Saninn	–	–	1/83	1	1/39～1/63	5
Setouchi	1/100	1	1/82～1/86	3	1/44～1/65	3
Southern Shikoku	–	–	1/56	1	1/41～1/51	3
Kyusyu	–	–	1/90～1/100	4	1/60～1/90	14
All Japan	1/90～1/145	7	1/22～1/100	28	1/25～1/90	47

Declining the degree of safety against flood by increasing future rainfall



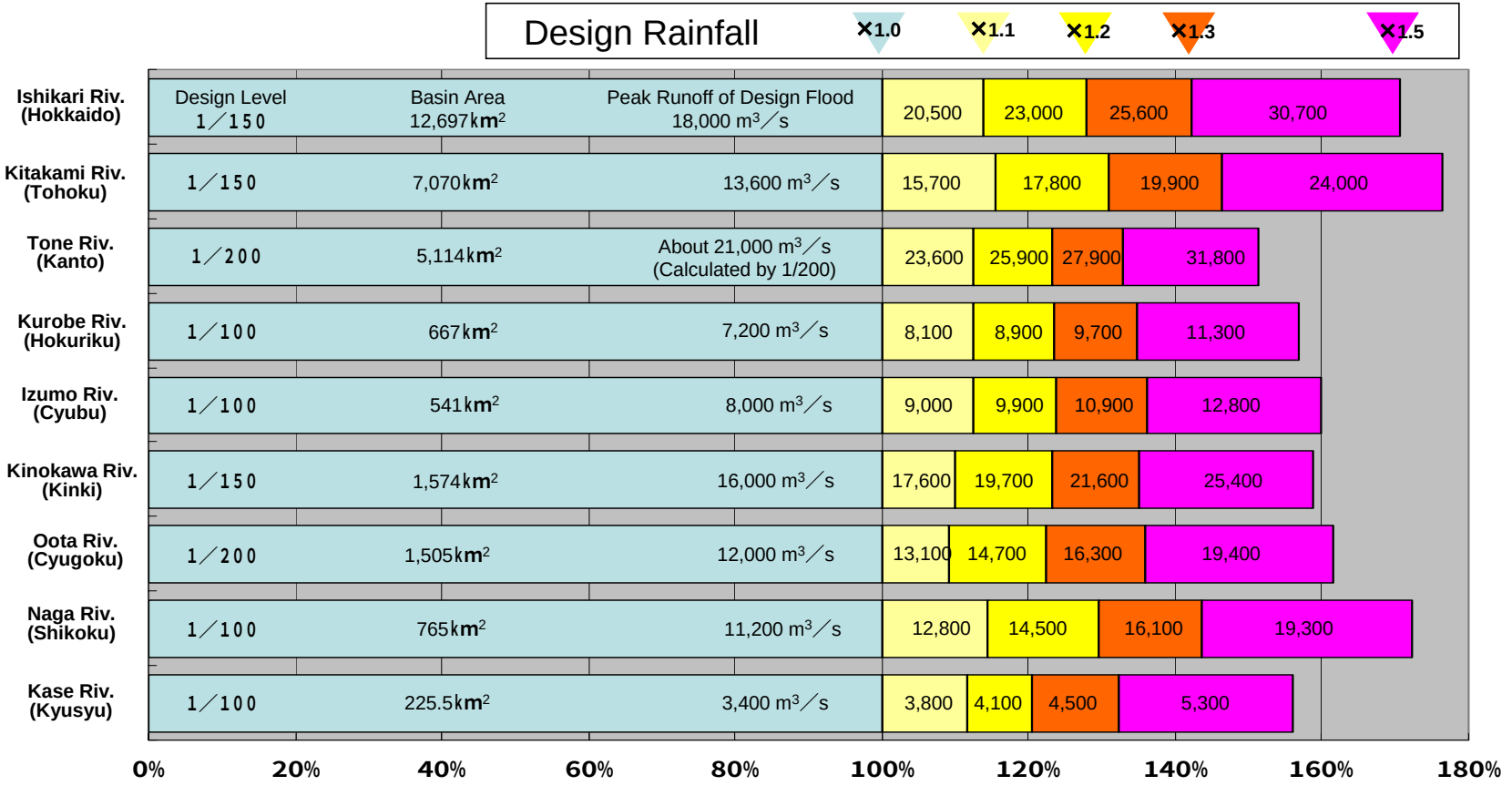




※ Circled number is number of calculated river system

Changes of peak runoff by future rainfall

Estimations of future rainfall are about ×1.0 ～×1.5 compare to current rainfall. Peak runoff will be estimated about ×1.0 ～×1.7 compare to current rainfall in 9 major rivers.

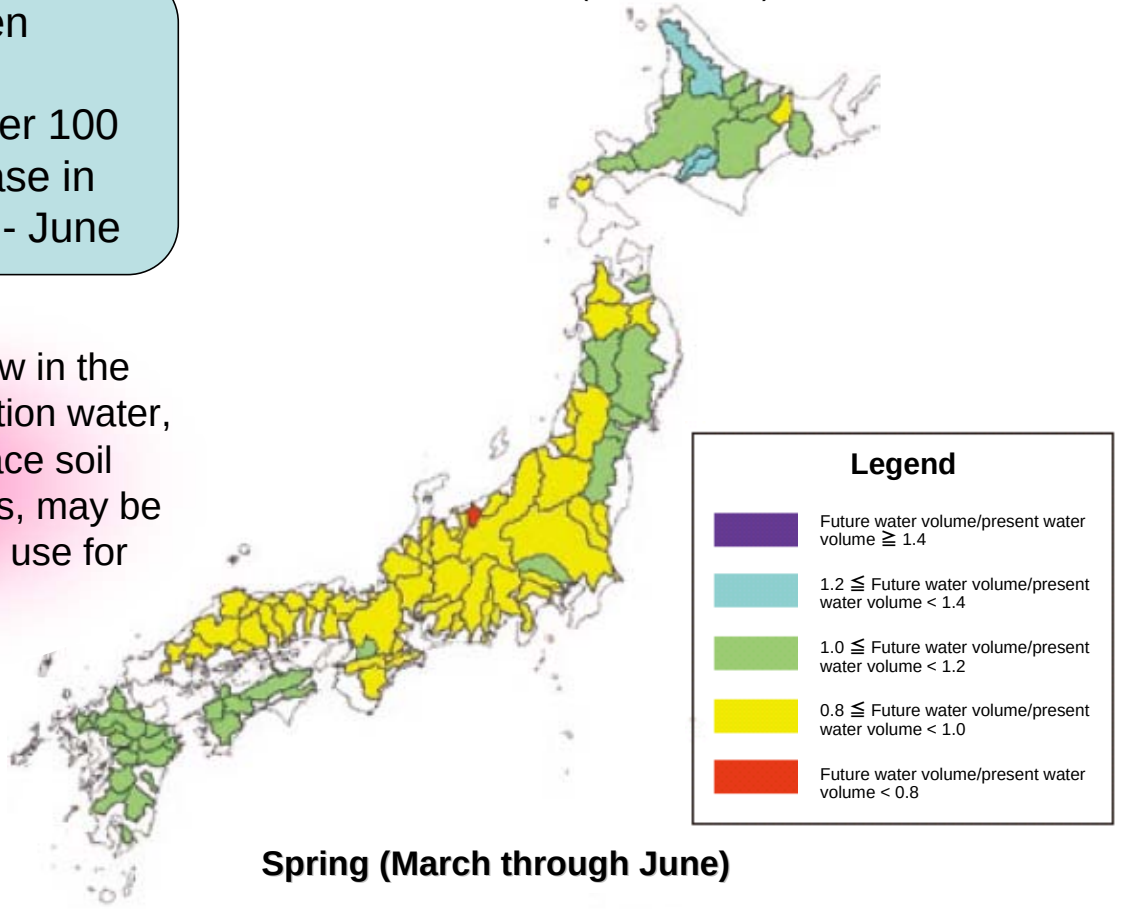


More frequent and serious droughts

Comparison between present rainfall and predicted rainfall after 100 years shows decrease in most area in March - June

Reduction of river flow in the periods requiring irrigation water, e.g. during the surface soil puddling in paddy fields, may be deteriorated to water use for rice farming.

Comparison between present conditions(1979 to 1998) and future rainfall(2080 to 2099) in Class A river



Spring (March through June)

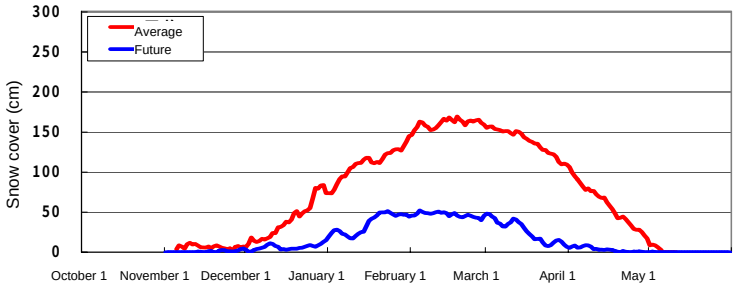
Source: Water Resources in Japan 2007, Land and Water Bureau, Ministry of Land, Infrastructure and Transport

Frequent and more serious droughts

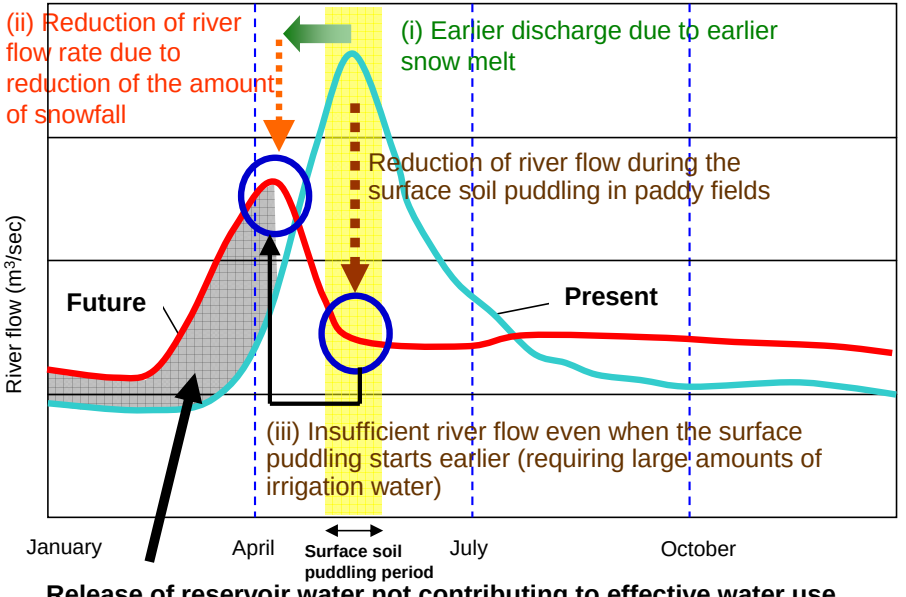
In the upper Tone River, snow cover is likely to decrease considerably. That will accompany the reduction of river flow rate in the snow melt season or in early spring.

With global warming,
(i) earlier snow melt and (ii) reduction of snowfall induce changes in river flow rate, and
(iii) earlier surface soil puddling in paddy fields is expected to cause the annual water demand pattern to change and to have serious impacts on water use.

Change in snow cover in 100 years' time due to further global warming (Fujiwara)



*Prepared by Water Resources Department, Water and Land Bureau, Ministry of Land, Infrastructure and Transport based on Regional Climatic Model (RCM) 20, a global warming prediction model, developed by Japan Meteorological Agency.

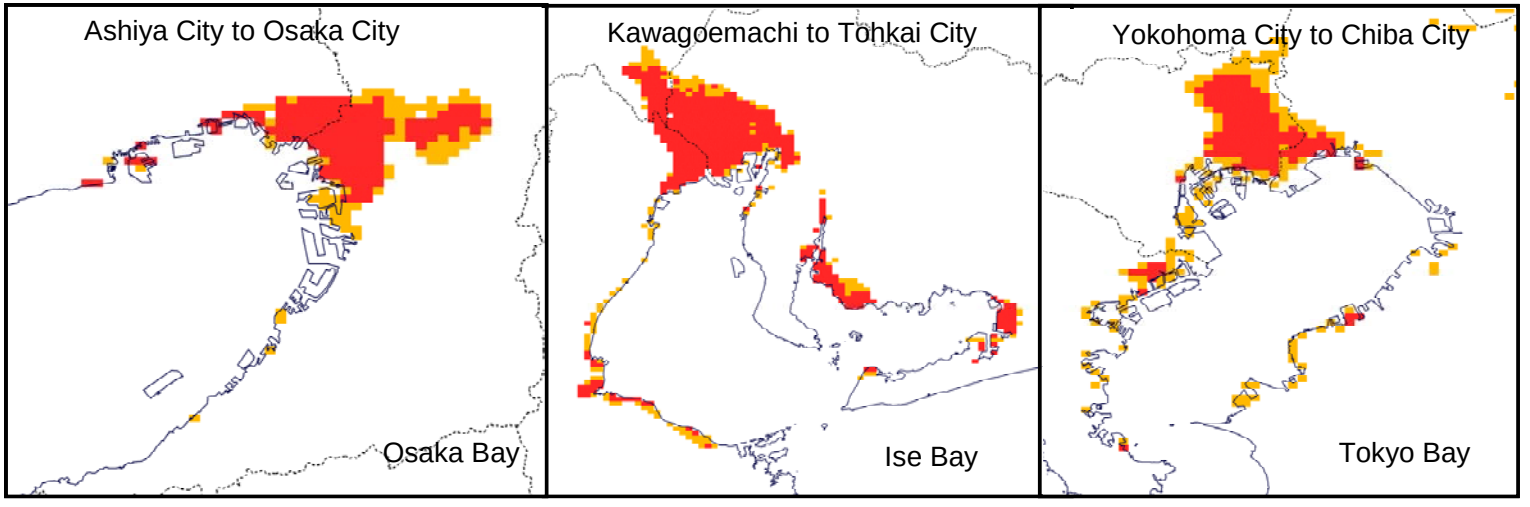


Release of reservoir water not contributing to effective water use
Where the reservoir is full, released water is not used effectively.

Source: Water Resources in Japan 2007, Land and Water Bureau, Ministry of Land, Infrastructure and Transport

Impacts of sea level rise:
Increase of areas below sea level, and of risks of inundation due to high tides

Increases of below-sea-level areas in three large bay areas (Tokyo Bay, Ise Bay and Osaka Bay)



Areas with flood risks due to high tides will increase.

*Prepared by the River Bureau based on the national land-use digital information.
*Shown are the areas at elevations lower than sea level shown in a three-dimensional mesh (1 km x 1 km). Total area and population are based on three-dimensional data.
*No areas of surfaces of rivers or lakes are included.
*A premium of 60% is applied to the potential flood risk area and to the population vulnerable to flood risk in the case with a one-meter rise of sea level.

	Present	After sea level rise	Rate of increase
Area (km^2)	577	879	1.5
Population (Million)	4.04	5.93	1.5

Recommendations of this study

Climate change due to global warming is expected to induce the following phenomena in coastal and low-lying areas.

-More frequent heavy rains and more intense typhoons

⇨ Frequent and serious flood and sediment disasters

-Sea level rise and more intense typhoons

⇨ Frequent and serious high tides and coastal erosions

-Wider range of variation of rainfall intensity and change of river flow regime

⇨ Frequent and serious droughts

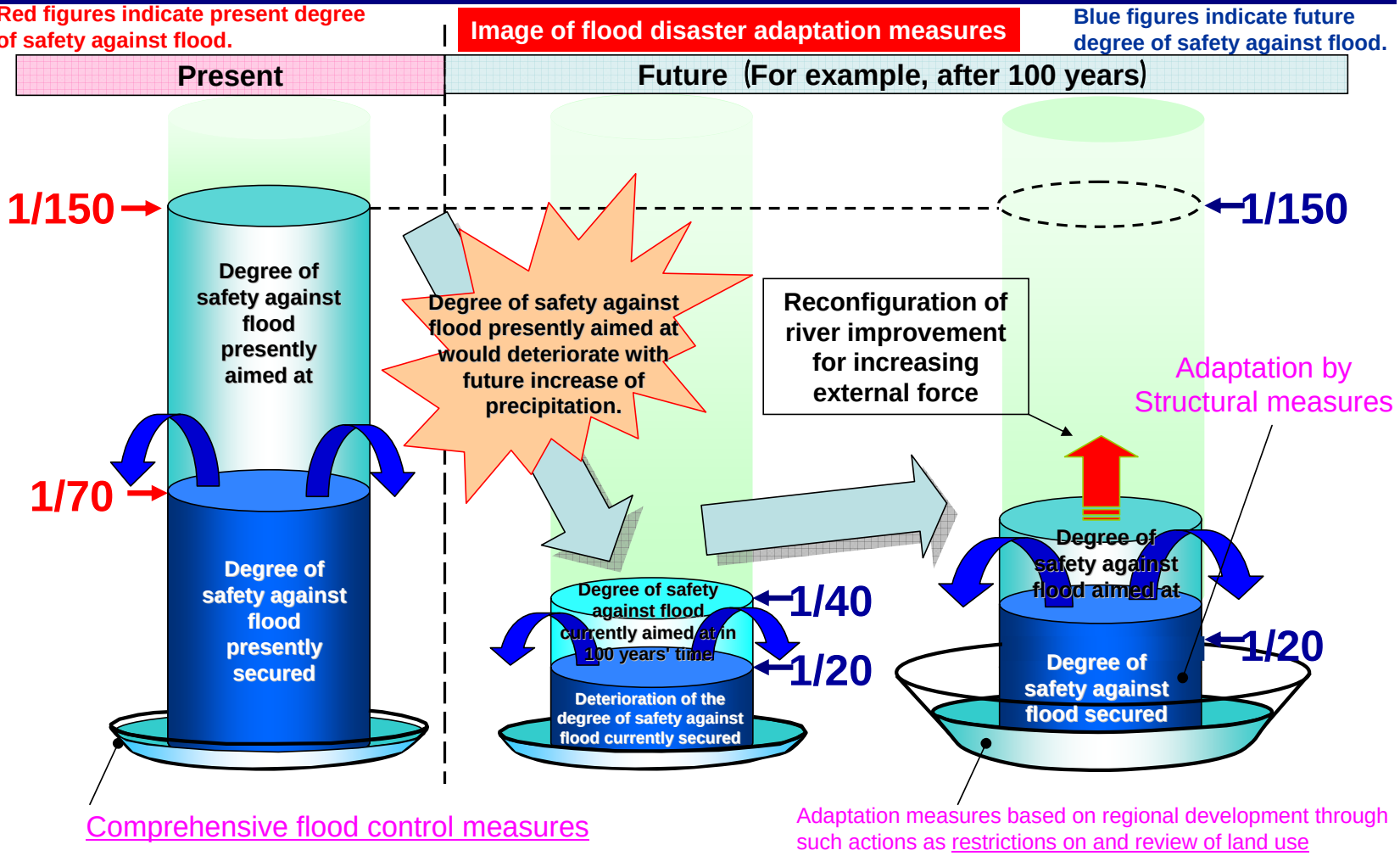
Recommendation1. Basic concept for Future ideal society

Combining mitigation and adaptation aiming at ‘’Sustainable and Water Disaster Adaptable Society’’

Recommendation2. Basic direction of climate change adaptation measures

1. Adaptation measures to achieve "zero casualty" should be considered because ‘’Zero damage’’ from disasters is difficult.
2. In a nerve center like the Tokyo metropolitan area, intensive efforts should be made such as preventing from ceasing national function

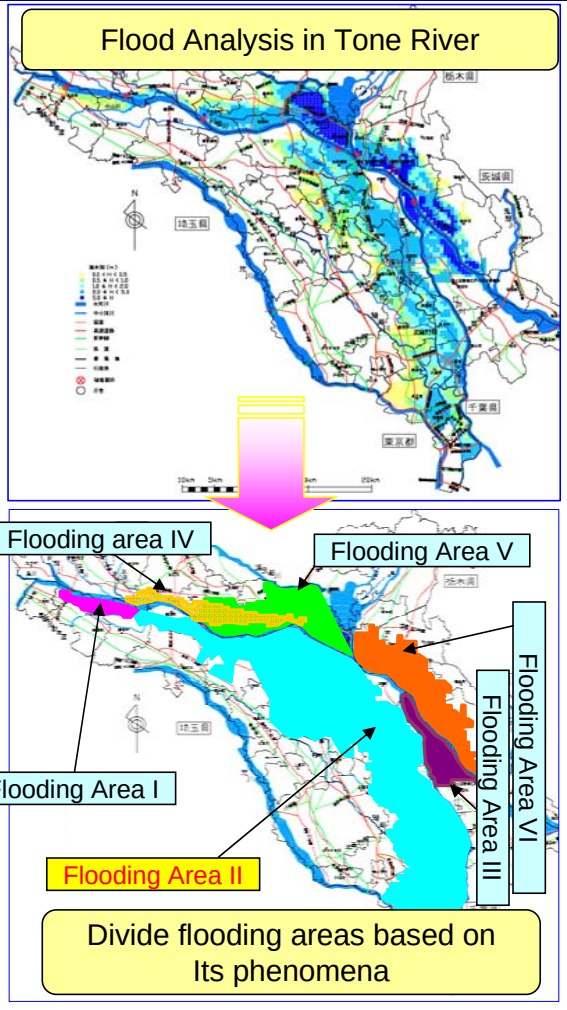
Recommendations3. Multiple measures for increasing in hazard

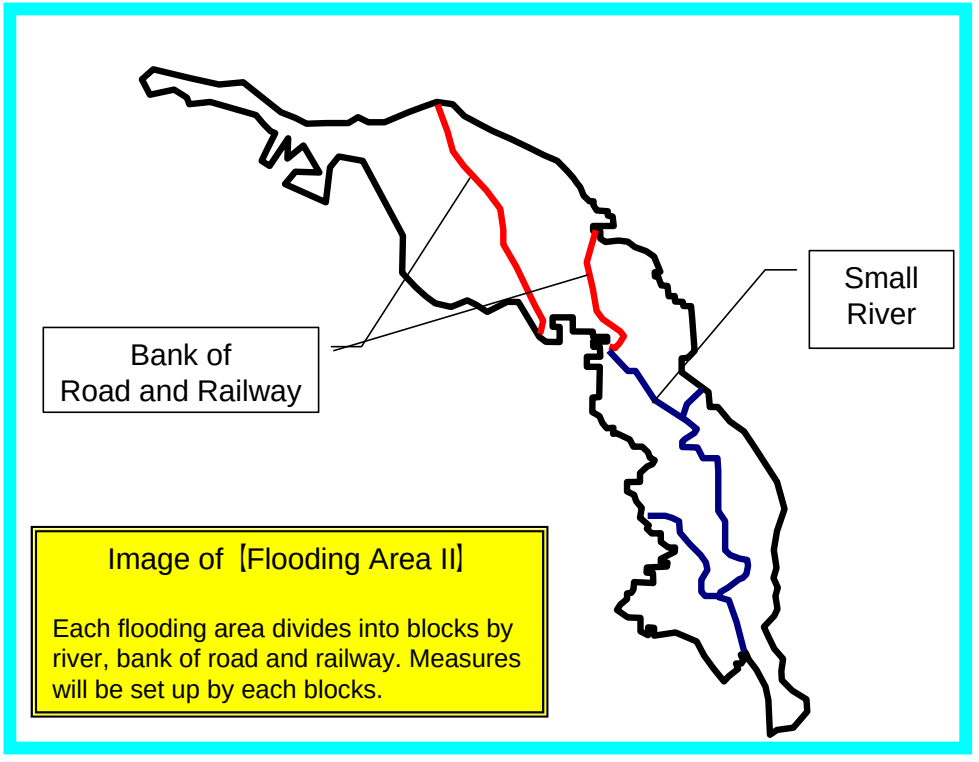


Recommendation4. Importance of Flood Risk Assessment

6. Japan's response to climate change

- ex) Adaptation measures programming in river basin





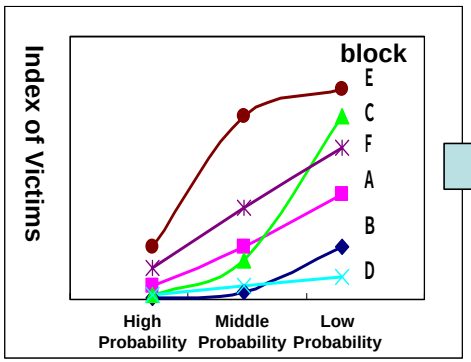
Recommendation4. Importance of Flood Risk Assessment

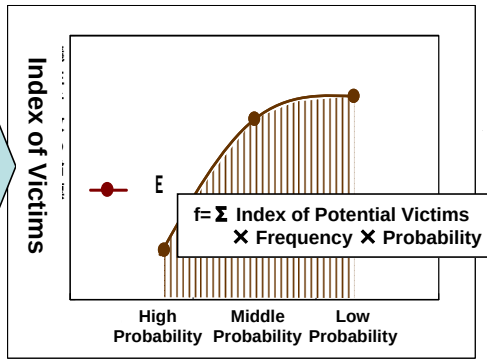
- Concept of Flood Risk Assessment

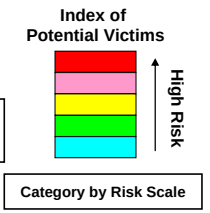
[Hazard Index] is increasing by Climate Change. For reduction of [Disaster risk] , increasing [Disaster Prevention Index] and reducing [Affection Index] by adaptation measures such as improvement of facility, revise of land use, enforce of emergency response

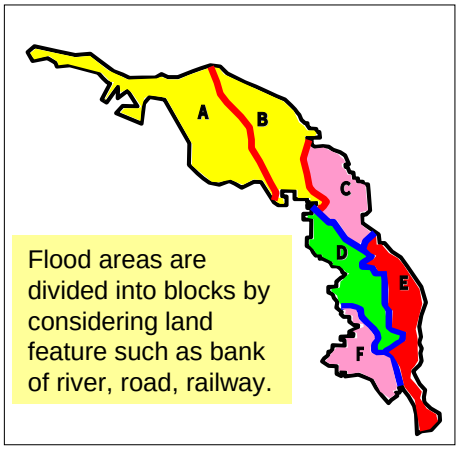
$$\text{Disaster Risk} = \frac{\text{Hazard Index} \times \text{Affection Index}}{\text{Disaster Prevention Index}} \times \text{Probability}$$

- Hazard Index : Natural hazard and Land condition
  (Climate, Hydrology, Land Feature, Geologic Condition, etc and Scale of Hazard)
- Affection Index : Social vulnerability of disasters
  (Inundation people, Inundation houses, impacts of Road, Railway, Lifeline, etc)
- Disaster Prevention Index : Disaster prevention activity by Central Government, Local Government, community
  (Present status of facility improvement, Public preparedness for disasters)









Recommendation4. Importance of Flood Risk Assessment

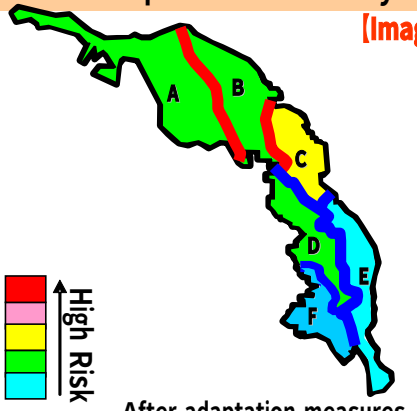
6. Japan's response to climate change

- Evaluation of risks and programming adaptation measures

Programming based on considering evaluation items, alternates and costs in each and mutual drafts

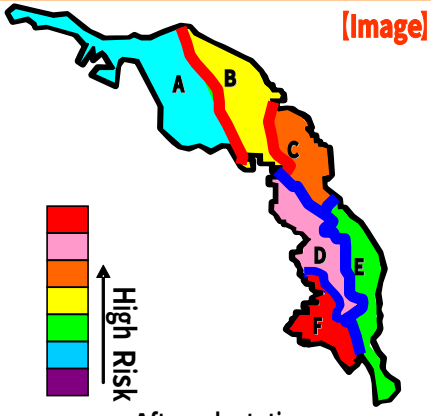
■ Index of potential casualty

[Image]



■Index of economic damage

[Image]



Necessity of considering multiple index of affection

Example of Affection Index

Affection Index f

- Potential Casualty
- Economic Damage
- Administrative Services Depression
- Inundate House
- Environmental Damage

Maximize target function under restriction of assessment contents and adaptation measures etc.

$$\Delta f = f_1 - f_2$$

$$\sum_{i}^{n} \alpha_i \cdot \Delta f_i \Big/ \sum_{i}^{n} C_i$$

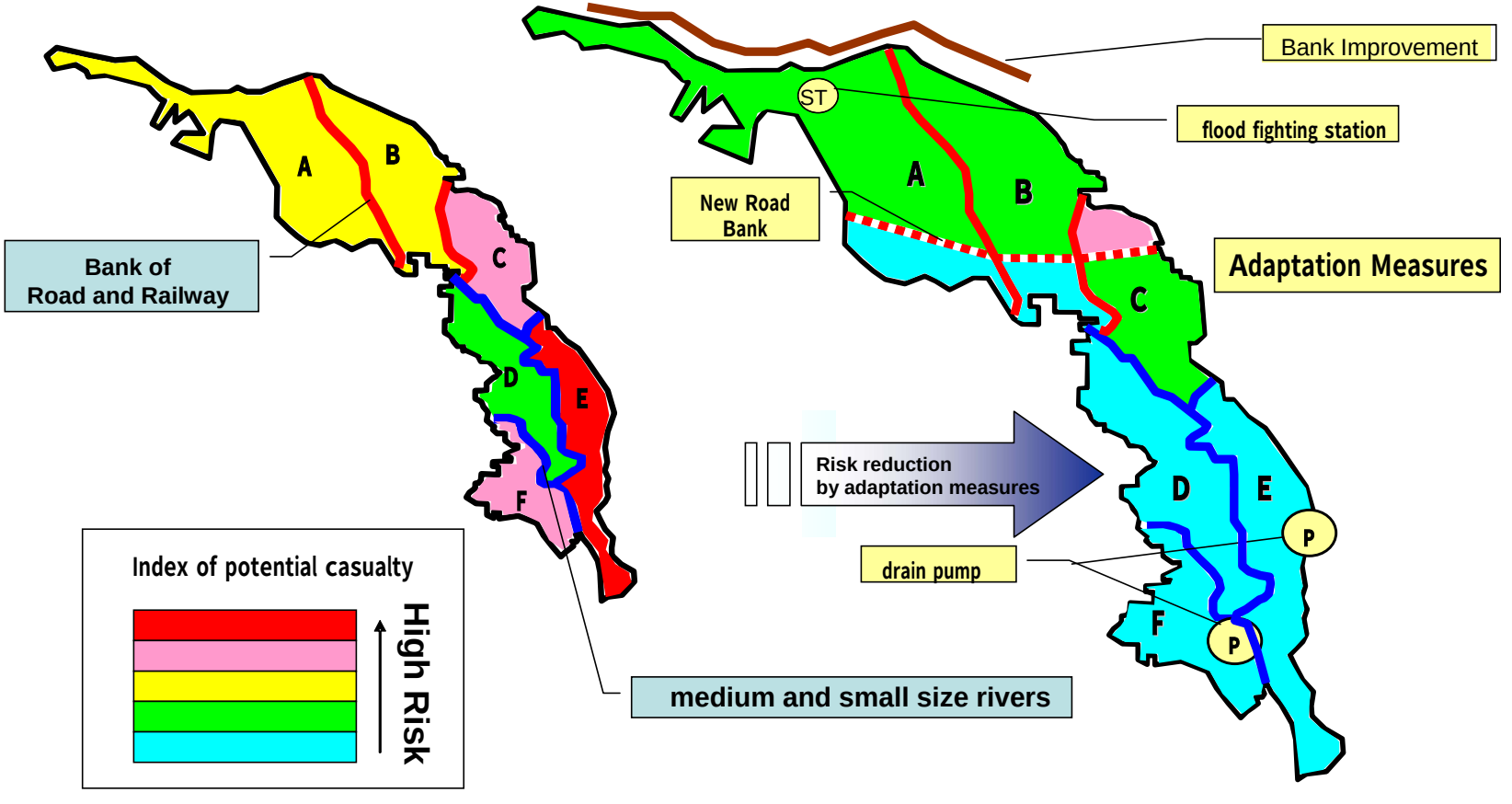
f_1 : Current Affection Index
f_2 : Affection Index after adaptation measures
Δf : Reduction of Affection Index by adaptation measures
α_i : Weighting factor of each assessment Affection Index
n : Targeted evaluation items
C : Cost

Recommendation4. Importance of Flood Risk Assessment

6. Japan's response to climate change

- Evaluation Risks and Programming adaptation measures

Expression effectiveness of risk reduction by adaptation measures by color difference



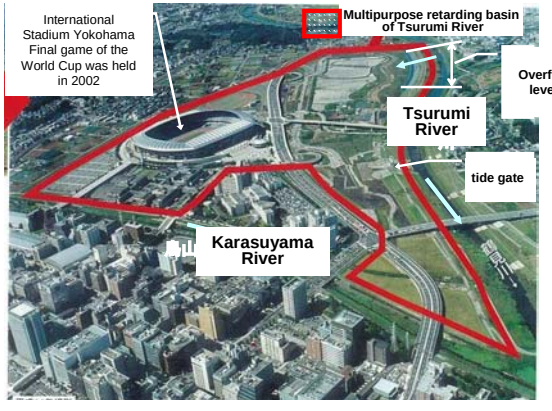
Recommendation5. Appropriate combination of practical measures

- Adaptation measures by using structural method

6. Japan's response to climate change

Improvement of the credibility of structure, effective and multipurpose and long-life utilization of existing structure

Improvement structure



Multipurpose retarding basin of Tsurumi River

flood control (Dam)

River improvement of Tsurumi river

improvement of the credibility of structure (ex Coastal protection)

Before

aging revetment by deteriorated concrete

After

Rehabilitation of aging revetment by setting up anterior wall

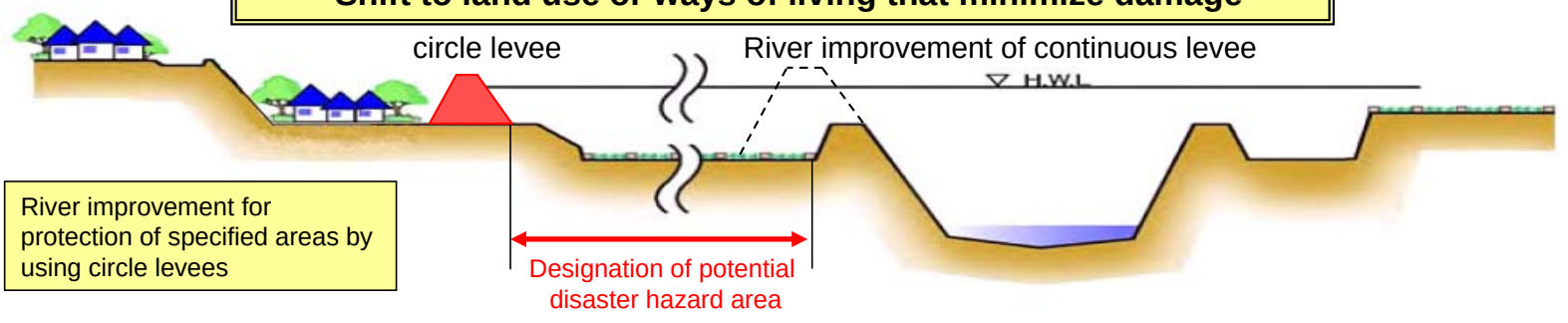
Recommendation5. Appropriate combination of practical measures

- Adaptation measures by using regional development

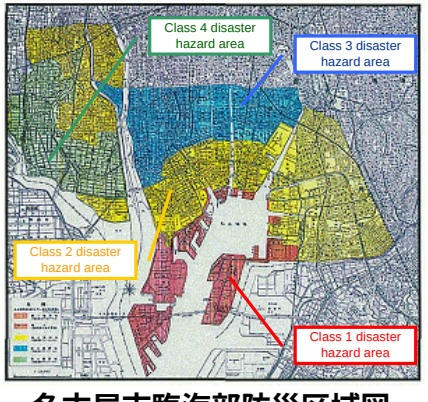
6. Japan's response to climate change

Response to floods that cannot be dealt with by facility-based measures, through land use or community development allowing inundation.

Shift to land use or ways of living that minimize damage

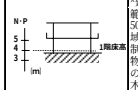
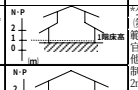
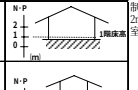
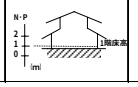


Restrictions on land use by designating potential disaster hazard areas



名古屋市臨海部防災区域図

Sample ordinance restrictions (Nagoya City)

		1階の床の高さ	構 造 制 限	図 解	
第1種区域	市街化区域	N・P (+) 4m以上	木造禁止		*建築物の建築禁止 範囲…海岸線・河岸線から50m以内で市長が指定する区域 制限…居住室を有する建築物、病院及び児童福祉施設等の建築禁止 木造以外の構造で、居住室等の床の高さをN・P (+) 5.5m以上としたものについては建築可能
第2種区域	市街化区域	N・P (+) 1m以上	2階以上に居室設置 緩和：延べ面積が100㎡以内のものは避難室、避難設備の設置による代替可		*公共建築物の制限 ：第2種～第4種区域 範囲…学校、病院、集会場、官公署、児童福祉施設等その他これらに類する公共建築物 制限…1階の床の高さN・P (+) 2mかつN・P (+) 3.5m以上の居室設置
第3種区域	市街化区域	N・P (+) 1m以上	――		
第4種区域	市街化調整区域	N・P (+) 1m以上	2階以上に居室設置		

Shift to community planning resistant to inundation

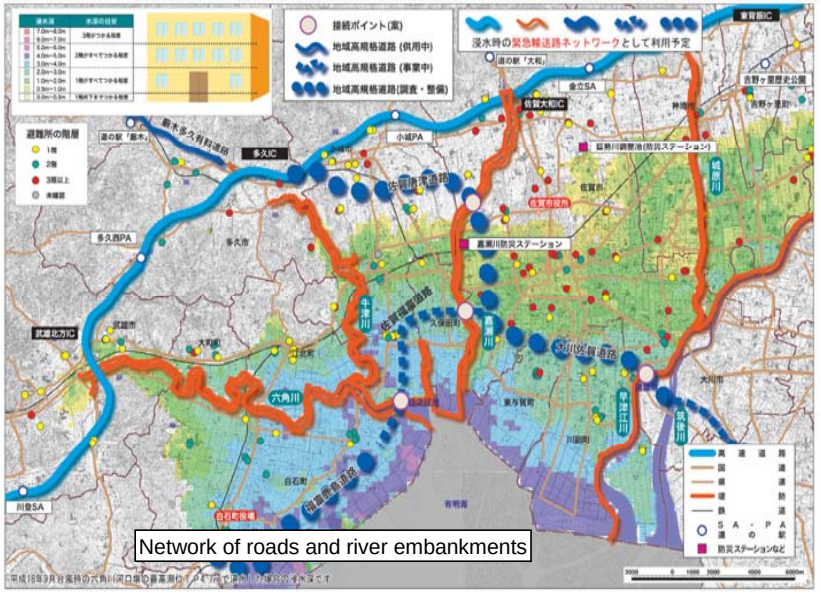
Adopting pilotis to prevent damage to buildings during a flood

Recommendation5. Appropriate combination of practical measures

- Adaptation measures centering around risk management

6. Japan's response to climate change

Building of a wide-area disaster prevention network that connects embankments, roads on the dry river bed for emergency traffic and elevated roads to wide-area disaster prevention bases.



Network of roads and river embankments

Inundation of Route 34 during a flood in July 1990

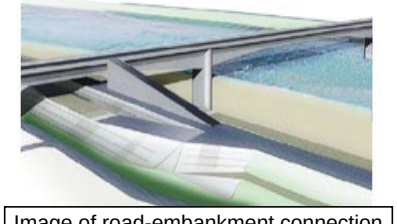


Image of road-embankment connection

Reinforcement of actions in the initial stages of a disaster for minimizing damage and restoring infrastructure early, and enhancement of an organizational setup to achieve the goal

Technical Emergency Control Force (TEC-FORCE)

TEC-FORCE

Organizational setup	
Field support center	Staff of Regional Development Bureaus and Offices
Wide-area infrastructure force (rivers, roads, sediment control, ports, etc.)	Engineers of National Institute for Land and Infrastructure Management and Public Works Research Institute
Sewerage system force	Technical support group (engineers)
Building land force	Private sector construction organizations (operators of equipment) (Contract/ agreement)
Buildings force	Coordination
	Staff of local public entities

Activities
-Investigation of damage
-Quick repairing
-Prediction of degree of damage risk
-Planning of control measures
-High-level technical guidance
-Assistance in reconstruction

Drainage pumping vehicle

Disaster control helicopter

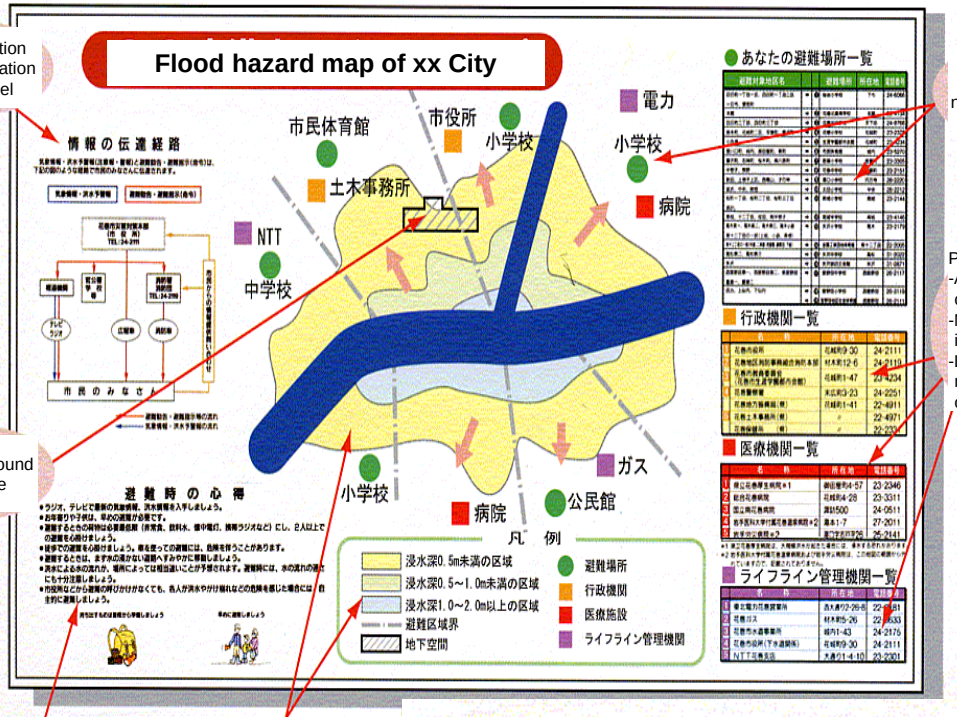
Recommendation5. Appropriate combination of practical measures

- Adaptation measures based on risk management

6. Japan's response to climate change

Share preliminary information concerning the degree of flood risk

Water levels in built-up areas in the past floods are indicated on the hazard map.



Information dissemination channel

Underground space

Hints on escape and necessities

Potential inundation areas and depths of inundation

Locations and names of shelters

Points of contact
-Administrative organizations
-Medical institutions
-Lifeline systems management organizations

Image of a flood hazard map

Toyooka City, Hyogo Prefecture

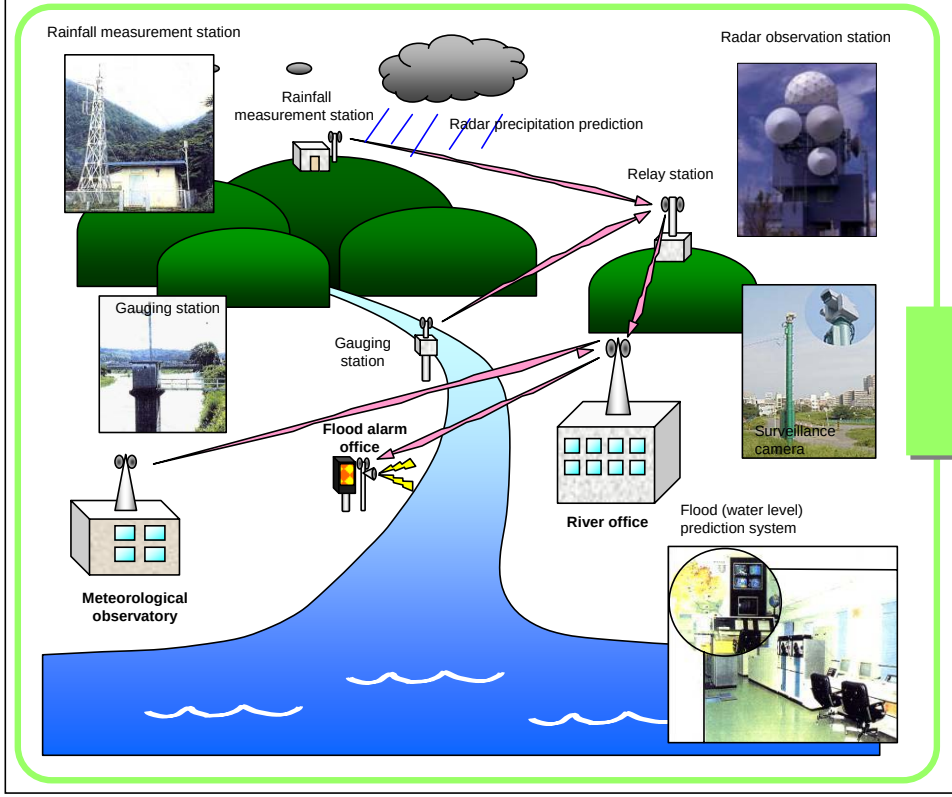
Easily recognizable signs

Recommendation5. Appropriate combination of practical measures

- Adaptation measures based on risk management

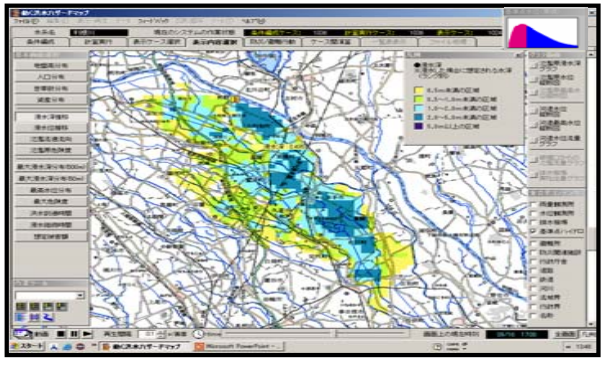
Share real-time information

- Provision of rainfall amounts and water levels real-time via cellular phone, the Internet or local disaster prevention radio
- Flood forecasting through real-time simulation



Information provision via cellular phone or personal computer

Delivery of an image to a TV screen



Floodwater prediction through real-time simulation

Considerations to be taken for implementation

(1) Inter-governmental efforts

(2) Promotion of cooperative work with the public

(3) Priority investment in preventive measures

(4) Clear prioritization

(5) Preparation of road maps

(6) Adoption of a flexible approach

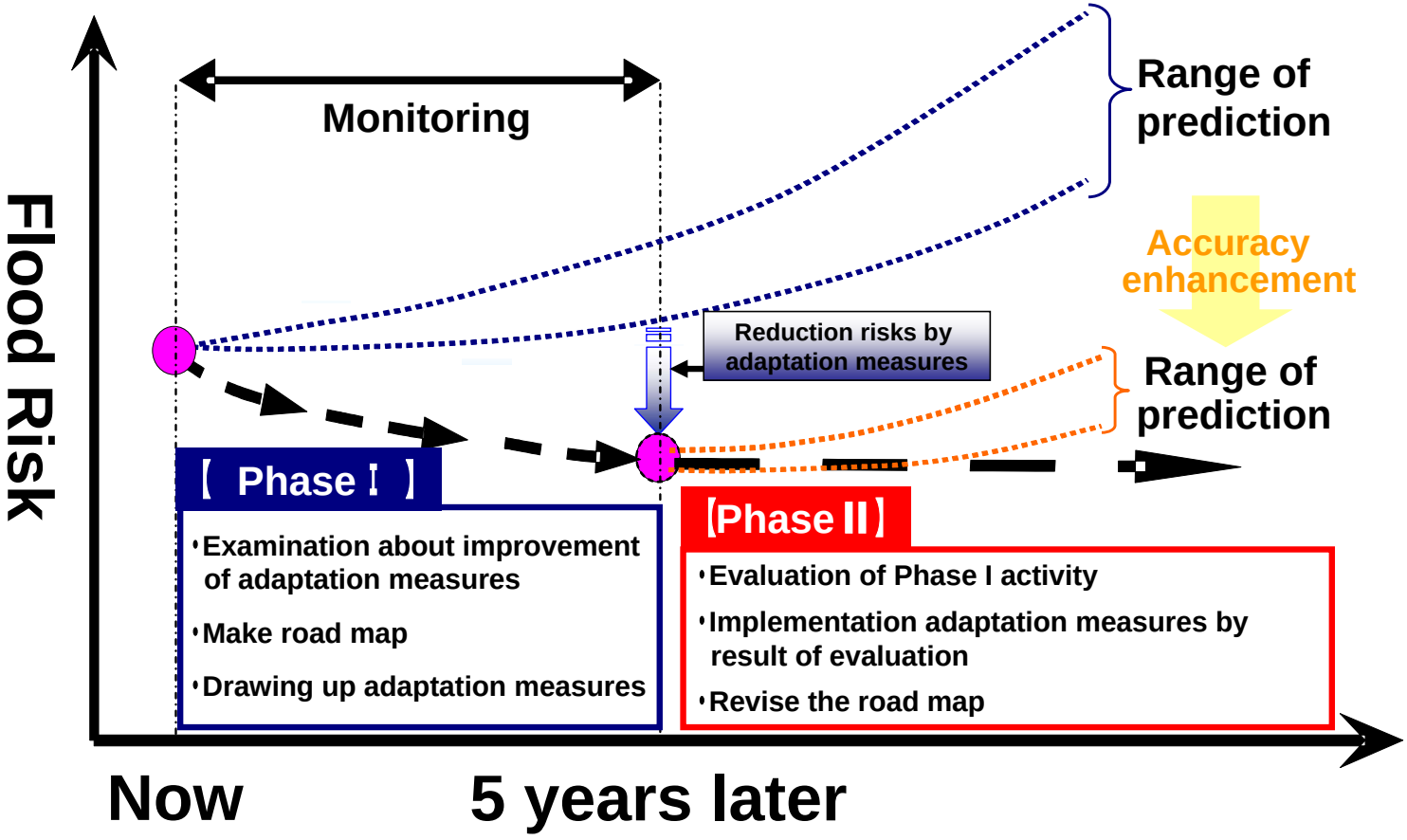
(7) Cooperation with related organizations

(8) Developing new technologies and contributing to the international community

(9) Promotion of research and application of their results to plan flood control, water use, and environmental conservation

Future timeline for implementation of this study

Revising adaptation measures by analysis of water-related disaster risks with improvement of flood prediction by monitoring changes of climate change and social condition.



Introduction on adaptation measures in Tsurumi river

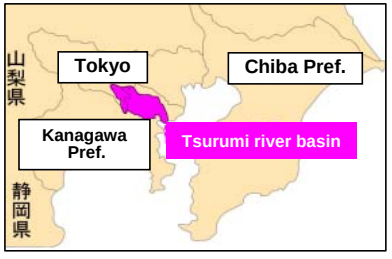
Outline of Tsurumi River (Geography)

Hill / tableland 70%

Alluvial lowland 30%

Riverbed gradient : 1/250

Middle section with stepped cross section



Densely-populated downstream section

Tsurumi River

Onda River

Tsurumi River

Hayase-River

Tsurumi River

Toriyama River

elevation

- 0～20m
- 20～40m
- 40～60m
- 60～80m
- 80～100m
- 100～120m
- 120～140m
- 140m～

Upstream section below grand level

Riverbed gradient：1/1,000

Outline of Tsurumi River (Urbanization and population increase)

Urbanization ration has increased

by **75%** in 50years

Rapid economic growth has turned natural area into urban area

1958 10%

450,000

1966 20%

700,000

Typhoon Karinogawa in Sep 1958

1975 60%

1,200,000

Present 85%

1,880,000

Typhoon No.17 in Sep 1976

Urbanization

Population

Natural Area

Urban Area

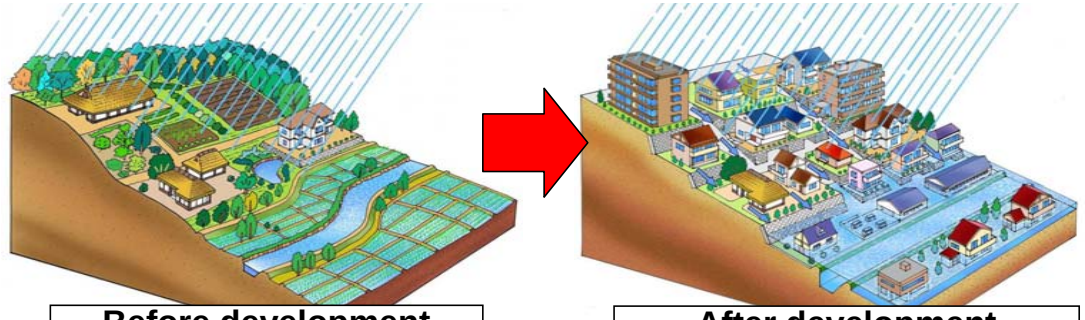
Outline of Tsurumi River (Effect of urbanization)

- Population increased by 1.4 million in 50 years
- 85% of river basin area urbanized
- Typical urban river

As a result

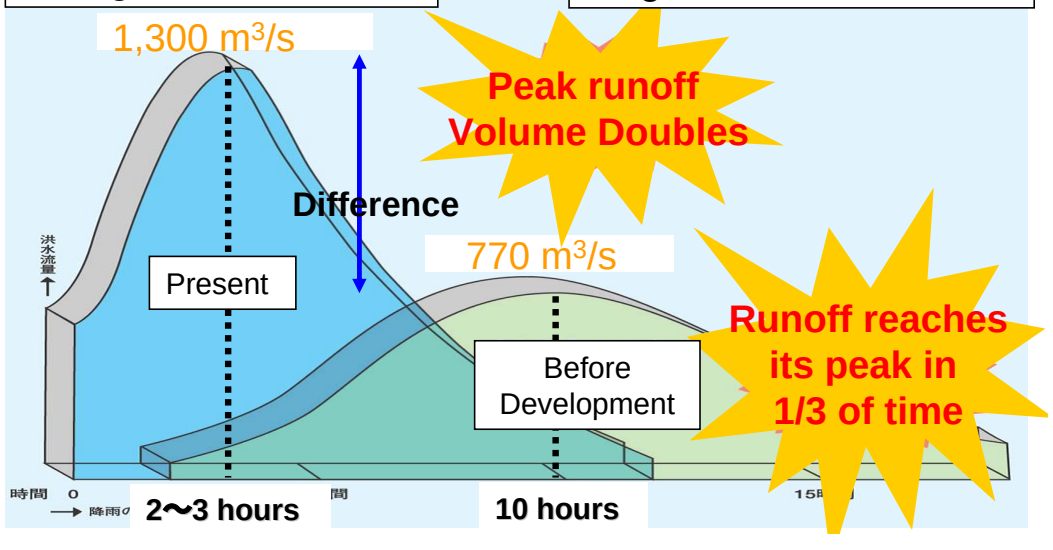
- Discharge into river has become faster
- Peak runoff has becomes bigger

Function of keeping and retarding water became weakened



Before development
Slight urbanization

After development
Significant urbanization



Basic strategy for controlling inundation damage
(Runoff allocation)

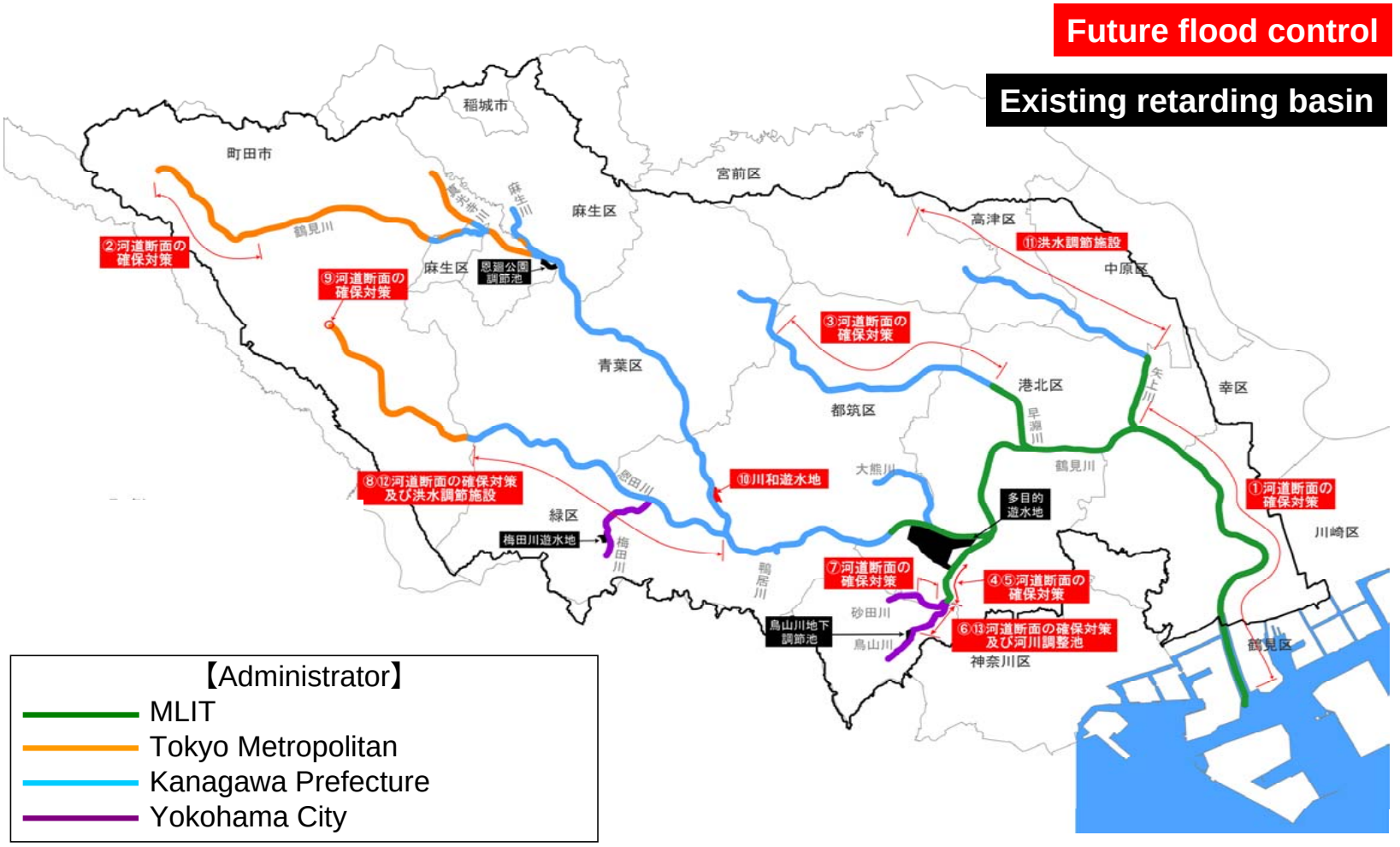
Runoff allocation by target rainfall

Peak runoff without discharge control ・・・2,110m³/s

- Allocation in river basin： 250m³/s
  - Existing and newly developed rainfall storage and infiltration facilities **205m³/s**
  - Rainfall storage and infiltration measures by municipalities **15m³/s**
  - Rainfall storage tubes by sewerage administrators **30m³/s**
- Allocation in river：1,860m³/s
  - Controlled by rivers **1,500m³/s**
  - Storage in flood control facilities and in retarding basins **360m³/s**

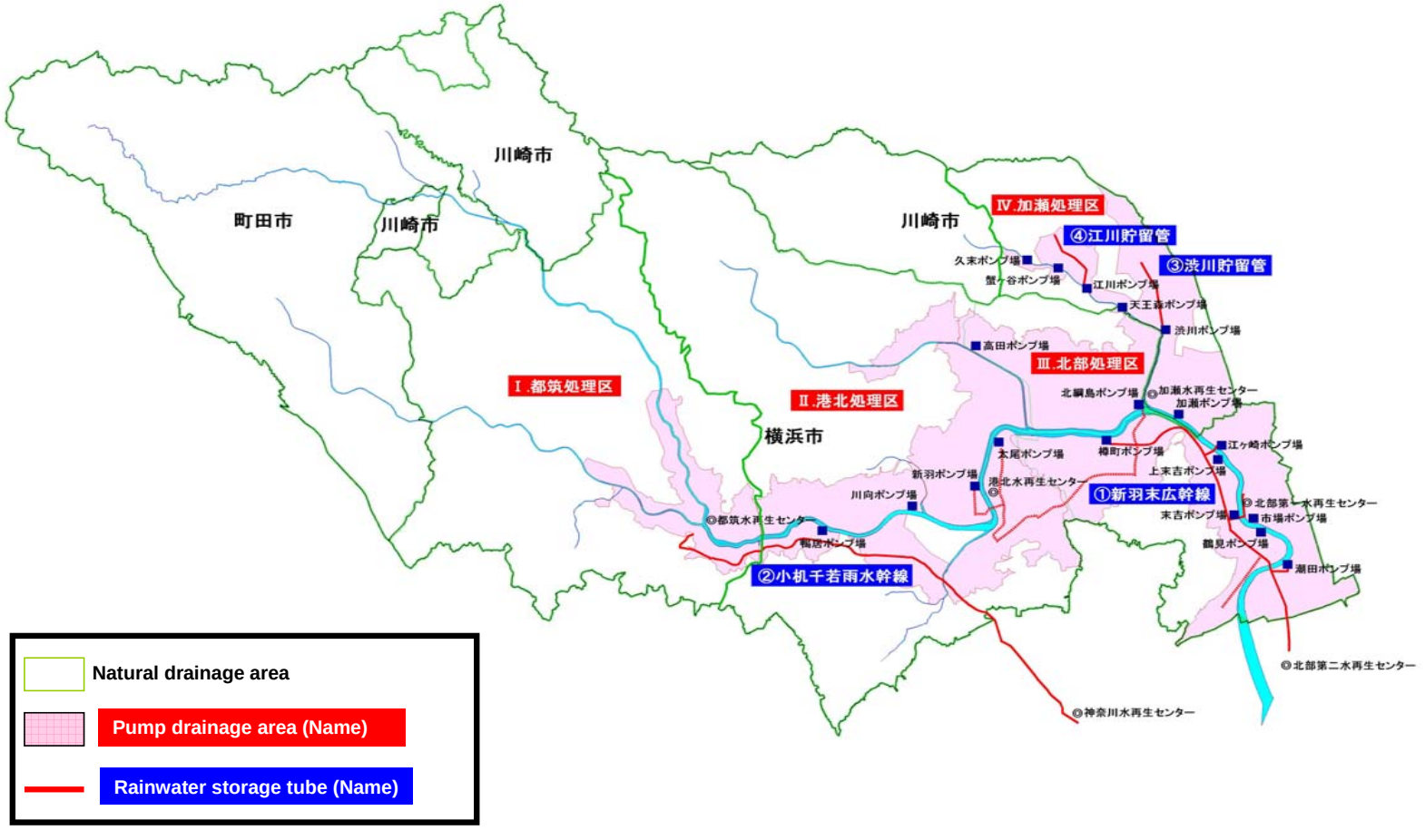
※Under the future land use, runoff is estimated at Sueyoshibashi point based on the largest rainfall after 1945.

River related projects in Tsurumi River Basin inundation control plan



Sewerage projects in Tsurumi River Basin inundation control plan

8. Adaptation measures in Tsurumi River



Rainwater storage facilities

Development of facilities for target rainfall

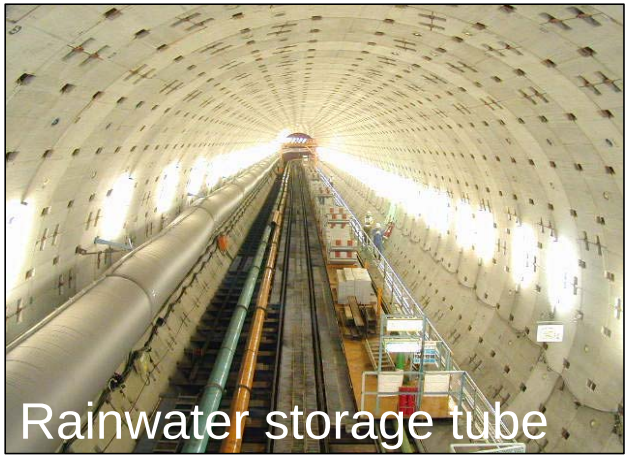
Planned discharge in pump drainage areas

City	Discharge area	Planned discharge
Yokohama	Tsuzuki	17m^3/s
	Kouhoku	142m^3/s
	Hokubu	189m^3/s
Kawasaki	Kase	55m^3/s
Total		402m^3/s

Planned storage of major facilities

City	Storage facility	Planned Storage
Yokohama	Shin hasue trunk line	**410,000m^3**
	Kozukue chiwaka trunk line	**256,000m^3**
Kawasaki	Shibukawa rainwater storage tube	**144,000m^3**
	Egawa rainwater storage tube	**81,000m^3**


Pump facilities


Rainwater storage tube

Storage, infiltration and forest conservation

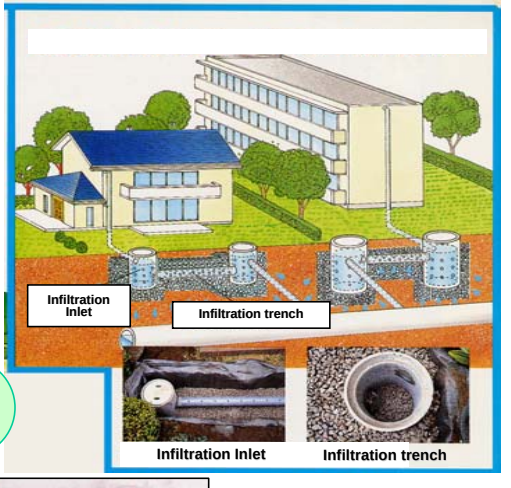
Development of rainwater storage and infiltration facilities, conservation of forested areas (Total effect by municipalities : 0.3 million m^3)

Storage

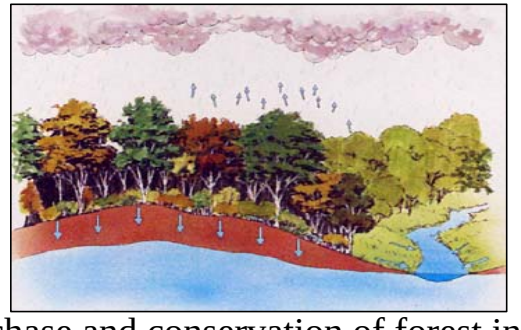
Storage facilities in schools, parks and public houses

Infiltration

Infiltration by permeable pavement



Forest Conservation



◆Purchase and conservation of forest in developing area

Operation rule of pumping station

Preparation of basic operation rules, communication, command and control, information sharing and public announcement

Basic rules of restricted pump operation

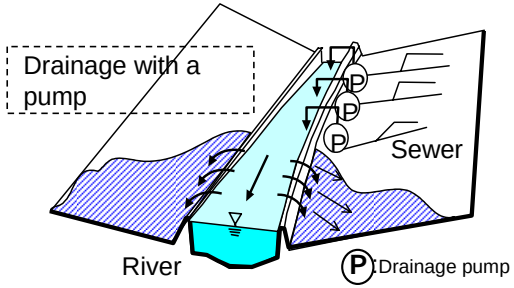
-River and sewerage administrators make basic rules of restricted pump operation to effectively decrease urban flood and inundation caused by heavy rainfall that exceeds the current project design target.

Communication and information sharing

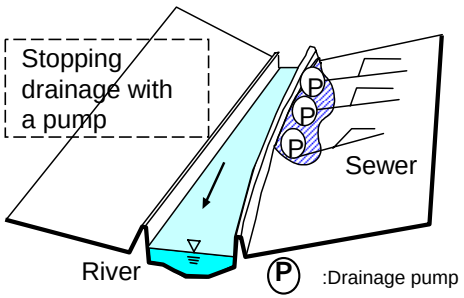
-Related organizations jointly establish communication system for effective and efficient pump operation.

-The administrators provide hazard information beforehand and ask for cooperation from residents. When pump operation is restricted, the administrators supply necessary information for residents' smooth evacuation.

《Image of flood damage by drainage pump》



Although surface water damage along river is mitigated by pump drainage, river water flood may occur at the bottle neck of water way in the downstream



Surface water damage may occur around the drainage pump due to drainage restrictions

Public awareness to mitigate damages

(Public awareness and education on disaster preparedness)

To organize local meetings and raise public awareness on preparedness on disaster

Education for pupils

Annual educational course for pupils on disaster preparedness at the Center

Tsurumi River Administration Center

Disaster preparedness caravan

To visit local meetings and explain to residents

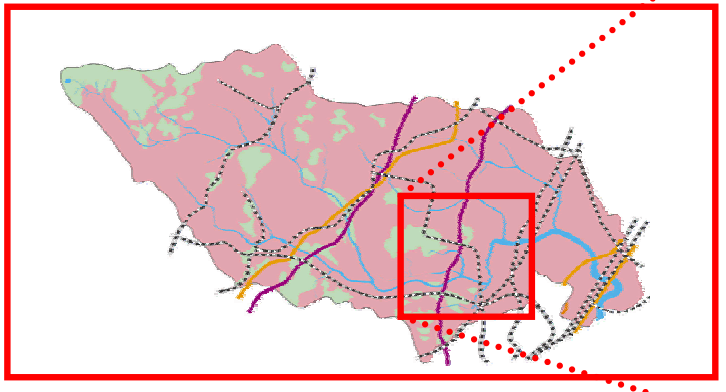
Public awareness on flood damages

(Advance dissemination of flood and inundation prone information)

By simulating urban flood and inundation, municipalities prepare “Hazard Maps”

Urban flood prone area (River administrator)	Urban inundation prone area (Sewerage administrator)
Flood is estimated by levee break or overtopping.	Inundation by insufficient drainage capacity is estimated.

On the basis



“Hazard Map” released by Yokohama City

Other measures (follow-up the plan)

Implementation, monitoring, evaluation and modification of the plan

Progress of major projects

- Implementation of river and sewage project

Installation of rainwater storage and infiltration facilities

- Installation of rainwater storage and infiltration facilities
- Countermeasures against blocking rainwater infiltration
- Progress of rainwater storage and infiltration facilities constructed for development based on regulations and guidelines

Changes of river basin

- Re-evaluation of latest development (area, location, type etc.)

Modification of the plan

International Activities

Contribution to International Organization

Contribution to WMO/GWP
(the Associated Programme on Flood Management)

●Purpose of Guideline

- Sustainable development considering flood risks which are changed by development
- Maximized social benefit in flood prone area for reduction of social vulnerability
- Minimized loss of life
- Conservation of environment

Japanese expert who related in WMO contribute to APFM which is producing IFM (Integrated Flood Management) guideline (2002～)

Contribution to WMO/ESCAP Typhoon committee

Technical contribution to hydrological component in terms of reduction of typhoon damages in asia-pacific region

2 regional incorporation programme (RIP) (Hazard Map and Landslide Warning System) are ongoing and holding workshop

Contribution to WWAP (World Water Assessment Programme)

WWAP from phase I in Oct 2000 to ongoing phase III, Since Japanese government strongly support WWAP financially and technically

Contribution to UNESCO's IRBM (Integrated River Basin Management)

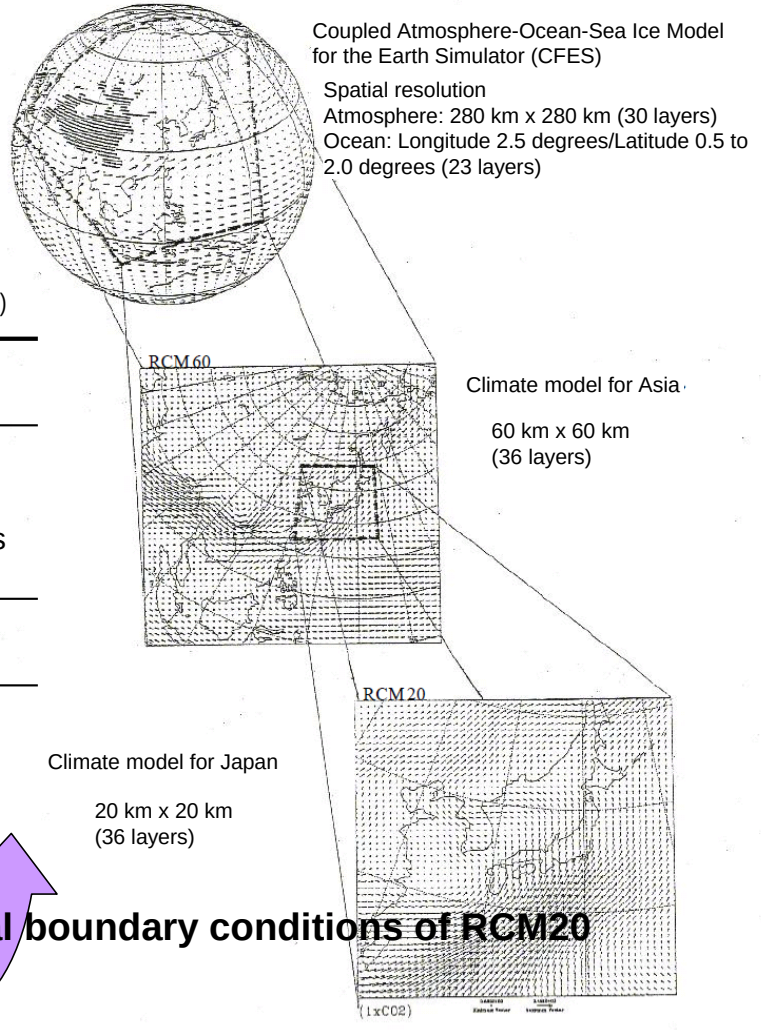
MLIT, JWA, ICHARM contribute their expertise and technology

Regional Climate Models (RCM20 and GCM20)

The recently developed simulation model enables more detailed regional climate prediction.

Regional Climate Models

	GCM20 (General Circulation Model)	RCM20 (Regional Climate Model)
Areas to be Calculated	Global scale	Japan and surrounding areas
Horizontal Resolution	About 20 km Number of meshes 1920 x 960	About 20 km Number of meshes 129 x 129
Number of Vertical Layers	60 layers	36 layers
Lateral Boundary Conditions	N/A, as this is a global scale model.	Climate model for Asia



Concept of lateral boundary conditions of RCM20