

**Climate Change Adaptation Strategies to Cope with
Water-related Disasters due to Global Warming
(Interim Policy Report)**

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Subcommittee on Climate Change Adaptation for Flood Control,
River Sector Committee,
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Introduction

Climate changes that accompany anthropogenic global warming (hereinafter referred to as “climate change”) are a serious issue as they are predicted to cause serious and large-scale adverse impacts, including those that may also shake the foundation of people’s life, as well as those on ecosystems, water resources, foods, coastal and low-land areas, industries, and human health. In coastal and low-land areas, especially, both the frequencies and scales of floods, sediment disasters and flood, sediment-related, storm-surge and other disasters are predicted to increase due to sea level rise, frequent heavy precipitation events and intensified typhoons. Serious droughts are also likely to increase due to a greater degree of fluctuation in precipitation. (These disasters are called “water-related disasters”.)

Amidst serious concerns over climate change, the Intergovernmental Panel on Climate Change (IPCC)¹ published its 4th report in 2007. The report suggests that nations should take adaptation since global warming mitigation have limitations and global warming impacts would continue over centuries even when mitigation is implemented.

This recognition has been seriously accepted by the international community. Some developed countries have already started taking some adaptation measures to climate change along with mitigation measures. They have systematically increase levee height while making efforts to reduce greenhouse gas emissions. On the other hand, in Japan, though one of the most disaster-vulnerable among developed countries, impacts of climate change on water-related disasters are still under scientific study, and practical adaptation measures to climate change have not yet been sufficiently discussed.

Considering that the safety and security of people is a basic duty of a

¹ Intergovernmental Panel on Climate Change (IPCC): An intergovernmental body consisting of international scientists to collect and analyze scientific studies on global warming.

national government, it must quickly investigate and implement flexible adaptation measures, including preventive structural measures, to cope with climate change based on long-term vision.

The subcommittee on climate change adaptation for flood control was established to originally analyze and assess climate change-induced changes in characteristics, such as frequency and scale, of flood, sediment-related, storm-surge and other disasters, and their impacts on society as well as to review adaptation strategies. While discussing, however, the subcommittee members emphasized the need of conducting investigations not only from a contracted viewpoint of conventional flood control but from various angles. Thus, the subcommittee decided to discuss and clarify the basic directions and contents of overall adaptation to water-related disasters from latitudinous perspectives.

The subcommittee met four times from August to November 2007 and issued an interim policy report on adaptation strategies for climate change. A wide range of opinions on the report will be collected in various manners, and the subcommittee will continue discussion and will issue the final report on the theme.

I. Common recognition

(Needs of taking urgent adaptation strategies)

Since 70% of the national land of Japan is mountainous, about a half of the population and three-fourths of the total property exist in alluvial plains, which account for only 10% of the area. Areas below sea level in the three major bays of Japan (Tokyo, Ise and Osaka Bays) occupy an area of 577 km², accommodating 4.04 million habitants. In Japan, which is located on the circum-Pacific orogenic zone, mountains are steep, rivers are short and steep, many faults and landslide-prone areas exist; thus, the country is topographically and geologically prone to disasters. The islands are also located on the eastern end of the Monsoon Asia, which is characterized by high precipitation, and suffer from extremely severe meteorological conditions – a mean annual precipitation of about 1,700 mm (twice the world average), frequent typhoon disturbances, and extreme rainfall events in which almost 200 mm-per-hour precipitation was recorded. The land is thus vulnerable to flood, sediment-related, storm-surge and other disasters.

Flood control projects, such as levee and flood-storage structure development, have been implemented to conquer the disaster-prone conditions and have improved the flood safety level. However, the construction of planned flood control structures has been slow and remains at a low completion level, only reaching about 60% of the government's mid-term goal, which is set to implement flood control measures against rainfall with a return period of 30-40 years for large rivers and 5-10 years for small and medium rivers.

Although the mean annual precipitation is twice the world average, the per capita precipitation is only one-third the world average, suggesting that there is not abundant water for regular use. The steep and short rivers of Japan quickly discharge collected water to the sea, and the difference between the maximum and minimum discharges is large, making stable water use difficult. In addition to these natural conditions,

water supply and demand became increasingly imbalanced due to the population increase and rapid economic growth. Japan managed to cope with these problems by constructing facilities and structures for water resources development. On the other hand, urban water demand has leveled out due to recent changes in the industrial structure and the promotion of efficient water use, and has been balanced with supply despite some local variations. However, there is a tendency that annual precipitation fluctuates more widely and extremely low precipitation years become more frequent, which may lead to higher drought risk and lower reliability of water supply.

The IPCC 4th Assessment Report touches upon a situation for which past data and experience would not be practically useful since climate change would cause large-scale sea level rise, more intense storms and typhoons, and more serious droughts. Therefore, areas where disaster mitigation systems have been planned and executed based on past meteorological data and experience would possibly suffer even more devastating damage due to increases in scale and frequency of flood, sediment-related, storm-surge and other disasters, including serious droughts.

For those reasons, the national government of Japan should take immediate action to plan adaptation measures to climate change. Social structures need to be reconstructed so as to enhance further disaster resistance in order to protect the national land by taking prevention measures for coastal erosion, as well as prevention/mitigation measures for flood, sediment-related, storm-surge, drought and other disasters.

(Adaptation and mitigation: the two wheels)

To reduce projected adverse effects of climate change, mitigation and adaptation are both considered necessary. The former is to mitigate climate change and variability by reducing or absorbing greenhouse gases. The latter is to avoid or reduce possible damage by developing systems to cope with climate change.

Country-specific greenhouse gas reduction goals were set as a mitigation measure in December 1997 when the Kyoto Protocol² was adopted at the Third Conference of the Parties to the Framework Convention on Climate Change³. The protocol states that Japan will lower overall emissions of greenhouse gases by 6% compared to the reference year (1990) over the first commitment period of 2008-2012. To achieve this goal, the Cabinet approved the Kyoto Protocol Target Achievement Plan⁴ in April 2005. The Ministry of Land, Infrastructure, Transport and Tourism has set reduction goals for transportation, civilian, and other sectors to contribute to the reduction of greenhouse gases.

Meanwhile, the IPCC 4th Assessment Report clearly states the importance of both mitigation and adaptation: “There is high confidence that neither adaptation nor mitigation alone can avoid all climate change impacts. Adaptation and mitigation can complement each other and together can significantly reduce the risks of climate change.” Both the measures are indispensable to cope with the impacts of climate change.

(Adaptation to climate change: a duty of a national government)

Observed data and projection results have shown trends of rising sea water level and increased frequency of heavy precipitation events. Although the phenomena are little or only partly understood, national governments must draw up appropriate adaptation strategies with help from experts before it is too late, since it is a basic duty of a national government to seek for the safety and security of citizens. Some

² The Kyoto Protocol: Agreed on December 1997 at the third Conference of the Parties to the treaty based on the United Nations Framework Convention on Climate Change. It set legally binding numerical goals for developed countries to reduce greenhouse gas emissions, and introduced a mechanism for internationally collective efforts to achieve such goals.

³ The Framework Convention on Climate Change: Officially called “the United Nations Framework Convention on Climate Change (UNFCCC or FCCC). It is a treaty which sets an international framework concerning global warming issues. The treaty is aimed at stabilizing greenhouse gas concentrations in the atmosphere.

⁴ The Kyoto Protocol Target Achievement Plan: Drawn up by Japan to plan and implement necessary measures to reduce its greenhouse gas emissions by six percent.

advanced countries have already developed or started working on adaptation strategies.

(Proposing effective adaptation strategies)

Effective adaptation strategies should be proposed after thorough discussion from the viewpoints of rationality, efficiency and effectiveness. Possible impacts of climate change need to be closely reviewed to minimize damage by avoiding extreme destruction. In addition, adaptation strategies should be planned to cover various subjects, such as the national land and society, in terms of flood control, water use and river environment, by revising issues and problems of existing structures for such use.

(Introducing a flexible approach)

Adaptation measures should be planned using a “flexible” approach by which they will be revised based on future observational data and accumulated knowledge about the impacts of climate change on sea level, precipitation and river flow. Thorough consideration should also be paid on social conditions, such as population decrease, decline of birthrate and aging population, and land use change, and also on circumstances related to flood control/water use measures, such as available funds, completion level of planned structure development, and current/past flood control plans.

(Contributing to the international community)

Flood, sediment-related, storm-surge, drought and other disasters caused by climate change occur in global scale and are common issues facing members of the international community, although the degree of the impacts varies depending on region. Some of the Asia-Pacific countries especially share similar climatic and geological conditions to those in Japan in that they are located in the Monsoon Asia and have their production and living bases on alluvial plains. Also, in those countries, population is rapidly growing, and water-related problems are becoming more serious. It is important that Japan offers its experiences, strategies,

and technologies to help those countries and contribute to the international community.

II. Intensification of external forces and impacts on national land and society

II-1. Descriptions of climate change in the IPCC 4th Assessment Report

The IPCC 4th Assessment Report was published during the year 2007; the Working Group I Report in February, the Working Group II Report in April, the Working Group III Report in May. The report describes changes in air temperature, sea level, and other meteorological features as well as their impacts as follows:

(Observed changes in climate and their effects)

- Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice and rising global average sea level.

- The 100-year linear trend (1906-2005) was 0.74 [0.56 to 0.92]⁵ per 100 years.

- Rising sea level is consistent with warming. Global average sea level has risen over 1961 to 2003 at an average rate of 1.8 [1.3 to 2.3] mm per year and since 1993 at 3.1 [2.4 to 3.8] mm per year, with contributions from thermal expansion, melting glaciers and ice caps, and the polar ice sheets. Whether the faster rate for 1993 to 2003 reflects decadal variation or an increase in the longer-term trend is unclear.

- From 1900 to 2005, precipitation increased significantly in eastern parts of North and South America, northern Europe and northern a central Asia but declined in the Sahel, the Mediterranean, southern Africa and parts of southern Asia. Globally, the area affected by drought has likely increased since the 1970s.

⁵ Numbers in square brackets indicate a 90% uncertainty interval around a best estimate, i.e. there is an estimated 5% likelihood that the value could be above the range given in square brackets and 5% likelihood that the value could be below that range. Uncertainty intervals are not necessarily symmetric around the corresponding best estimate.

- It is likely that the frequency of heavy precipitation events has increased over most areas. It is likely that the incidence of extreme high sea level has increased at a broad range of sites worldwide since 1975.
- Changes in snow, ice and frozen ground have with high confidence increased the number and size of glacial lakes, increased ground instability in mountain and other permafrost regions and led to changes in some Arctic and Antarctic ecosystems.
- There is high confidence that some hydrological systems have been affected through increased runoff and earlier spring peak discharge in many glacier- and snow-fed rivers.

(Causes of the observed changes)

- Global greenhouse gas (GHG) emissions due to human activities have grown since pre-industrial times, with an increase of 70% between 1970 and 2004.
- Most of the observed increase in global average temperatures since the mid-20th century is very likely due to the observed increase in anthropogenic GHG concentrations.
- Advances since the Third IPCC Assessment Report show that discernible human influences extend beyond average temperature to other aspects of climate.

(Projections of future climate change and related impacts)

- Best estimates for global average surface air warming for the end of the 21st century (2090-2099) relative to 1980-1999 are 1.8°C under a scenario in which the global community balances environmental conservation and economic development and 4.0°C under a scenario with the highest GHG emissions.
- Ranges of sea level rise at the end of the 21st century (2090-2099)

relative to 1980-1999 are 0.18 to 0.38m under a scenario with the lowest GHG emissions and 0.26 to 0.59m under a scenario with the highest GHG emissions.

- It is very likely that hot extremes, heat waves and heavy precipitation events will continue to become more frequent.
- It is likely that future tropical cyclones will become more intense. There is less confidence in projections of a global decrease in numbers of tropical cyclones.
- Extratropical storm tracks are projected to move poleward, with consequent changes in wind, precipitation and temperature patterns.
- Increases in the amount of precipitation are very likely in high latitudes, while decreases are likely in most subtropical land regions, continuing observed patterns in recent trends.
- By mid-century, annual river runoff and water availability are projected to increase at high latitudes and decrease at mid-latitudes and decrease over some dry regions at mid-latitudes and in the tropics. Semi-arid areas will suffer a decrease in water resources due to climate change.
- Altered frequencies and intensities of extreme weather, together with sea level rise, are expected to have mostly adverse effects on natural and human systems.

[Asia]

- By the 2050s, freshwater availability in Central, South, East and South-East Asia, particularly in large river basins, is projected to decrease.
- Coastal areas, especially heavily populated megadelta regions in South, East and South-East Asia, will be at greatest risk due to

increased flooding from the sea and, in some megadeltas, flooding from the rivers.

- Climate change is projected to compound the pressures on natural resources and the environment associated with rapid urbanization, industrialization and economic development.
- Endemic morbidity and mortality due to diarrhoeal disease primarily associated with floods and droughts are expected to rise due to projected changes in the hydrological cycle.

[Small Islands]

- Sea level rise is expected to exacerbate inundation, flood, sediment-related, storm-surge and other disasters, erosion and other coastal hazards, thus threatening vital infrastructure, settlements and facilities that support the livelihood of island communities.
- Deterioration in coastal conditions, for example through erosion of beaches and coral bleaching, is expected to affect local resources.
- By mid-century, climate change is expected to reduce water resources in many small islands, e.g. in the Caribbean and Pacific, to the point where they become insufficient to meet demand during low-rainfall periods.

[Adaptation and Mitigation Options]

- A wide array of adaptation options is available, but more extensive adaptation than is currently occurring is required to reduce vulnerability to climate change.
- Additional adaptation measures will be required to reduce the adverse impacts of projected climate change and variability, regardless of the scale of mitigation undertaken over the next two to three decades.

- Some planned adaptation is already occurring on a limited basis. Adaptation will reduce vulnerability to climate change, especially when embedded within broader initiatives.
- Selected examples of planned adaptation in water and infrastructure/settlement (including coastal zones)

sector	Adaptation option/strategy	Underlying policy framework	Key constraints and opportunities to implementation (Normal font = constraints; <i>italics</i> = opportunities)
Water	Expanded rainwater harvesting; water storage and conservation techniques; water reuse; desalination; water-use and irrigation efficiency	National water policies and integrated water resources management; water-related hazards management	Financial, human resources and physical barriers; <i>integrated water resources management; synergies with other sectors</i>
Infrastructure /settlement (including coastal zones)	Relocation; seawalls and flood, sediment-related, storm-surge and other disasters barriers; dune reinforcement; land acquisition and creation of marshlands/wetlands as buffer against sea level rise and flooding; protection of existing natural barriers	Standards and regulations that integrate climate change considerations into design; land-use policies; building codes; insurance	Financial and technological barriers; availability of relocation space; <i>integrated policies and management; synergies with sustainable development goals</i>

(The long-term perspective)

- The five reasons for concern to consider the impacts of climate change
 - a) An increasing risk to unique and vulnerable systems, such as polar and high mountain communities and ecosystems, is projected.
 - b) The risks of extreme weather events, such as droughts, heat waves and floods, are projected to increase.
 - c) Regionally or socially vulnerable groups of people likely face greater impacts of and exhibit greater vulnerability to climate change.

- d) Benefits from climate change are projected to peak at a lower magnitude. There will be higher damages for larger magnitudes of global temperature increase, and the costs of impacts of increased warming are projected to increase over time.
 - e) The risks of large-scale abrupt changes, such as sea level rise and accelerated ice-sheet melt, very likely increase.
-
- There is high confidence that neither adaptation nor mitigation alone can avoid all climate change impacts. Adaptation and mitigation can complement each other and together can significantly reduce the risks of climate change.
 - Adaptation is necessary both in the short term and longer term to address impacts resulting from the warming that would occur even for the lowest stabilization scenarios assessed.
 - Sea level rise under warming is inevitable. Thermal expansion would continue for many centuries after GHG concentrations have stabilized, for any of the stabilization levels assessed, causing an eventual sea level rise much larger than projected for the 21st century. The eventual contributions from Greenland ice sheet loss could be several meters, and larger than from thermal expansion, should warming in excess of 1.9 to 4.6°C above pre-industrial be sustained over many centuries. The long time scale of thermal expansion and ice sheet response to warming imply that mitigation strategies that seek to stabilize GHG concentrations at or above present levels do not stabilize sea level for many centuries.

II-2. Descriptions of climate change in Japan in different assessment reports

The Japan Meteorological Agency has published several documents reporting on climate change in Japan as follows:

(Observed meteorological trends)

- The mean annual temperature in Japan has increased at a rate of 1.07°C per 100 years since 1898, when observational data was first available. (#2)
- Rainfall fluctuations between years have become greater although no long-term trend has been observed in annual precipitation. (#2)
- Extremely low monthly precipitation has significantly increased annually. There is no significant long-term trend in extremely high precipitation. (#2)
- There was a significant increasing trend during a 106 year period from 1901 to 2006 in number of days with a daily precipitation of 100mm or more or of 200mm or more. The number of days with 100mm or more in the last 30 years is about 1.2 times as high as those in the first 30 years of the 20th century, while days with 200mm or more is about 1.4 times as high. (#2)
- There has been an increasing trend in short-time heavy rainfall (50mm or more per hour or 80mm or more per hour) in the last 30 years. (#2)
- Decadal trends in annual average deepest snow cover were calculated for the northern, eastern and western coastal zones on the Japan Sea side based on the 1962-2004 time-series changes in annual average deepest snow cover of those coastal zones. The calculation results were -4.7%, -12.9% and -18.3% for the northern, eastern and western coastal zones, respectively, and show a significant decreasing trend for the eastern and western coastal zones. (#1)
- There was no clear trend during the period of 1951 to 2006 in number of typhoons generated, approaching and landing on Japan. (#2)
- Mean deviations of annual average tide levels at five tide stations were calculated relative to the average tide level during the period of 1906 to

2004, and then the average mean deviations were calculated to use them as indices to find out the average sea level changes around Japan. The results show no statistically significant increasing trend in sea level around Japan in the last 100 years. Since the mid-1980s, however, the sea level around Japan has continued to rise and has reached the highest level in the last 100 years, which is as high as the 1950 level. ^(#1)

- It has been pointed out that there is the possibility that the recent sea level rise is due to different factors (e.g. thermal expansion due to ocean warming) than those for the 1960-1990 sea level changes. ^(#1)

(Simulation results based on RCM20⁶ under the A2-type scenario⁷)

Global warming was simulated based on a regional climate model (RCM20) under the A2-type scenario, and climate change in Japan about 100 years from now (2081-2100) was forecasted as follows relative to the climate conditions of the present time (1981-2000) ^(#3):

- Temperature in general is projected to be higher all over Japan throughout the year. In particular, the temperature is projected to rise at a higher rate from winter to spring in northern Japan.
- Mean annual temperature is projected to rise approximately 2 to 3°C (4°C in part of Hokkaido, the northernmost prefecture of Japan).
- Precipitation is projected to decrease from winter to spring in many parts of Japan, while increasing during the period between the summer and fall rainy seasons.
- Annual precipitation is projected to increase in most parts of Japan. In particular, western Japan is projected to experience a higher rate of increase, e.g. as high as 20% in some areas.

⁶ RCM20 (Regional Climate Model 20): A regional climate model to simulate climatic conditions in Japan and its surrounding areas. Horizontal resolution: 20km x 20km.

⁷ A2-type scenario: Assumes a heterogeneous world, in which economy and politics are primarily regionally oriented, trades and movement of people and technologies are limited, economic development is slow, interests in the environment are also low.

The reports of the Japan Meteorological Agency cited in this section:

(#1) *Ijo-kisyo Report 2005* (2005 Report on Extreme Meteorological Events)

(#2) *Kiko-hendo-kanshi Report 2006* (2006 Report on Climate Change Monitoring)

(#3) *Kiko-ondanka-yosoku-joho vol.6* (Global Warming Forecast Information, vol.6)

- Summer precipitation is projected to increase especially in western Japan, while it is projected to fluctuate to a greater extent in eastern Japan in forthcoming years.
- Heavy rainfall events are projected to become more frequent in most parts of Japan. The number of days with a daily precipitation of 50mm or more is projected to increase by three days or more per year, particularly in some coastal zones on the Japan Sea side in western Japan.

II-3. Intensifying external forces

“External forces” refer to climatic factors, such as precipitation, that are subject to the impacts of climate change, and also to the impacts of resultant phenomena, such as floods, droughts, sediment run-off, storm surges and other disasters.

1. Change in precipitation

The IPCC 4th Assessment Report was prepared based on global-scale projections. To precisely understand the impacts in Japan and use the knowledge for policy making, investigations are needed using downscaling⁸ models, which can precisely simulate phenomena around Japan.

Future changes in external forces were projected using intermediate-level scenarios although results contain some degree of uncertainty due to the capacities of computers and little-understood meteorological factors. Changes in flood discharge were estimated from those in precipitation.

The projection results showed that the rate of change would be 1.0 to 1.5 in RCM20 studies under the A2-type scenario⁹ when annual maximum daily precipitations were compared between the present time and 100 years later. A calculation using GCM20¹⁰ (Scenario A1B¹¹) showed different rates of change¹²; about 1.1 to 1.2 in general, 1.3 in some regions, such as Tohoku and Hokkaido, and 1.5 at the highest.

Using the calculated results in RCM20 (A2-type scenario) studies, the rates of change in 100-year return-period maximum daily precipitation

⁸ Downscaling: Translating predictions of coarse resolutions into detailed resolutions that can reproduce regional climate characteristics

⁹ Rate of change calculated using RCM20: (mean of 2081 to 2100) / (mean of 1981 to 2000)

¹⁰ GCM20 (General Circulation Model 20): A climate model for calculating the entire globe. Horizontal resolution: 20 km x 20 km

¹¹ Scenario A1B: Assumes a world of very rapid economic growth, in which global economy further develops, major revolution will occur in education, technology and some other areas, and a balance across energy sources is emphasized.

¹² Rates of change calculated using GCM20: (mean of 2080 to 2099) / (mean of 1979 to 1999)

in 50 and 100 years were calculated. The rate of change in 50 years¹³ was about 1.1 to 1.2, and that in 100 years¹⁴ was about 1.2 to 1.4.

Those results show that the reasonable estimation of precipitation in 100 years is about 1.1 to 1.3 times of the current value and 1.5 times at the highest.

The values were based on the projection available today, and further efforts should be made to improve projection reliability.

2. Increased floods

Impacts of the changes in rainfall in 100 years on river flood magnitude were reviewed. Of the class A rivers in Japan, one class A river was selected from each region. Flood safety levels¹⁵ of the present plans and in 100 years as well as changes in design flood peak discharge¹⁶ were calculated by multiplying design rainfalls and the ratios corresponding to the rates of change in rainfall in 100 years (1.1, 1.2, 1.3 and 1.5). Flood safety levels are expressed in annual probabilities of rainfall exceedance¹⁷.

(Flood safety levels and design flood peak discharges in 100 years)

Design rainfalls¹⁸ in current plans were enlarged by the aforementioned ratios, and associated annual probabilities of exceedance were calculated. The calculations showed that extremely high flood safety levels must be ensured in 100 years in order to ensure the present flood safety design levels, suggesting conventional

¹³ Rate of change in 50 years: (calculated values for 2031 to 2050) / (values calculated for 1981 to 2000)

¹⁴ Rate of change in 100 years: (calculated values for 20831 to 2100) / (values calculated for 1981 to 2000)

¹⁵ Flood safety level: Degree of safety of a river in flood control plan

¹⁶ Design flood peak discharge: Maximum discharge of the discharge not controlled by dams or other flood control structures

¹⁷ Annual probability of exceedance: Number of years in which an event occurs once. For example, rainfall of 1/10 in annual probability of exceedance is a rain that occurs once every 10 years or heavier.

¹⁸ Design rainfall: Rainfall used for drawing up flood control plans. Duration of a rain event and amount of rainfall during that duration are determined.

flood control measures alone cannot cope with the changes.

Estimation of 100-year return-period design flood peak discharges showed that peak discharges would increase along with increases in design rainfall but at higher rates. This shows that the larger changes in rainfall, the far larger peak discharges will become, which makes it more evident that conventional flood control would not work in the future as effectively as expected.

Table 1 Flood Safety Level under Climate Conditions after 100 years

Rate of increase in design rainfall	Flood safety level (annual probability of exceedance)	
	Current Climate Conditions	Climate Conditions after 100 years (probability under present climate conditions)
1.1 times	1/100	Approximately 1/200 ~ 1/300
	1/150	Approximately 1/400 ~ 1/500
	1/200	Approximately 1/500
1.2 times	1/100	Approximately 1/400
	1/150	Approximately 1/500 ~ 1/1,200
	1/200	Approximately

(Flood safety levels of the present plans)

Degradation of current plans' flood safety levels was calculated based on the projected changes in rainfall in 100 years. The results clearly showed that the safety levels dropped sharply, suggesting that the risks of floodings and inundations would be higher.

Table 2 Impacts of Changes in Precipitation after 100 years on Flood

Rate of increase in rainfall	Flood safety level (annual probability of exceedance)	
	Current Climate Conditions	Climate Conditions after 100 years (probability under present climate conditions)
1.1 times	1/100	Approximately 1/50 ~ 1/60
	1/150	Approximately 1/70 ~ 1/100
	1/200	Approximately 1/100
1.2 times	1/100	Approximately 1/20 ~ 1/40
	1/150	Approximately 1/40 ~ 1/80
	1/200	Approximately 1/60

3. Intensified debris flows

Climate change will alter the temporal and spatial distribution of rainfall and possibly cause increases in intensity and amount of precipitation, which may trigger sediment-related disasters, such as debris flows and landslides. It is also possible that climate change would accelerate weathering of the ground surface and affect the vegetation on slopes, which are causative factors of sediment-related disasters, although impacts are yet little understood.

Possible impacts of climate change on sediment-related disasters include increases in frequency and scale and change in timing of occurrence. More frequent sediment-related disasters may result in the expansion of landslide occurrence areas, i.e. landslide occurrences outside sediment-related disaster risk zones, and increase in

simultaneous sediment-related disasters at multiple locations. Particularly, unexpectedly heavy rainfall on areas that have little experienced such rainfall may cause severe sediment-related disasters. The time from the start of rainfall until landslide occurrences may become shorter, suggesting that there may be less time for safe evacuation. The scale of landslides is also likely to increase. Increased frequencies of deep-seated landslides may increase the amount of landslide mass and the debris coverage.

Increase in sediment discharge may cause floods containing a huge amount of sediment in the middle and lower reaches of rivers.

4. Intensified storm surges and coastal erosion

In the ocean, the heat only slowly propagates down to depths, causing seawater to expand for centuries. Thus, sea level rise would continue even if greenhouse gas concentrations were to be stabilized.

Since sea level rise is strongly affected by natural factors, such as multi-decadal changes in atmospheric flow and changes of the Japan Current, it is technically difficult to precisely project the degree of rise in each region, but the impacts of the phenomenon, which is relatively stable over a long period, can be taken into account to design structures.

As the intensity of typhoons increases, sea level is likely to rise due to their low atmospheric pressures, and the winds will cause strong drifts and high waves. Thus, intensified typhoons, besides sea level rise, are likely to increase damage caused by storm surges and coastal erosion.

5. Increased risks of droughts

Japan has faced some low precipitation years since 1965. Precipitations in 1973, 1978, 1984, 1994, 1996, and 2005 observed far less than mean annual precipitation, resulting in droughts. The difference between extremely low precipitation and extremely high

precipitation has expanded in recent years. Future climate change is possible to cause large-scale droughts equivalent to or even severer than the 1994 drought. Trends of decreased snow cover and earlier snow melt are also likely to be enhanced.

In Japan, urban water use amounts to approximately 28.3 billion cubic meters per year as of March 2007. At present, the water supply largely depends on water resources development structures/facilities, such as dams – specifically speaking, around 63% (about 17.8 billion m³/year) of the current urban consumption. The actual water supply capacities of the dam reservoirs in Japan have, however, become lower than the design supply capacities due to recent decrease in rainfall, which indicates a higher possibility of failing to secure stable water supply for urban and other uses. Also, in areas where people depend on snowmelt water for agriculture and other purposes, it is possible that people may suffer from serious impacts on water use during and after spring because of decreased snow cover and earlier snow melt.

II-4. Impacts on national land and society

Flood, sediment-related, storm-surge and other disasters due to climate change may have huge impacts on the national land and society, but the impacts may vary depending on topography, river morphology, and social and living conditions in basins. Thus, adaptation strategies should be developed for each basin by dividing a basin into upper, middle and lower basin areas and coastal zones. Appropriate strategies differ depending on zone, as described in the following examples.

1. Upper basin areas

In upper basin areas, mountainous regions typically suffer from forest degradation due to the lack of proper forest management which is caused by progressive depopulation and aging of communities. Therefore, sediment-related and windfall-tree disasters are likely to increase due to increased rainfall amount, higher short-time rainfall intensity, and more intensified typhoons. Sediment-related disasters, especially, may cause greater immediate damage due to increases in frequency and scale and changes in time of disaster occurrence.

More frequent and severer damage by sediment-related disasters will fatally affect mountainous communities, which already suffer depopulation and aging. Consequently, further emigration of younger community members will progress, and those communities will become extremely aged and ultimately disintegrated.

Also, increase in sediment run-off is projected to cause sediment deposition in flood control reservoirs in the lower reaches, hindering their capacities for flood control and water use. In addition, large quantities of sediment will also accumulate in river channels, blocking flood-water flow and thus deteriorating their flood safety levels. Increased sediment run-off will also prolong the period of turbid water.

2. Middle basin areas

In middle basin areas between mountainous regions and alluvial fans, flooding and inundation are projected to be more frequent due to levee breaches caused by heavier rainfall, higher short-time rainfall intensity, flooding from the upper reaches, and greater sediment run-off. In some middle basin areas, floods have been controlled by constructing levees, and land use in the flood plains has been changed from agricultural to residential use. Because of this land use change, open levees (called “*kasumi-tei*” in Japanese) have been closed, although originally designed to serve as retarding basins and also to help floodwaters flow back into the main streams. In flooding by levee breaches in alluvial fans, floodwaters will spread over large areas, causing widespread damage. Floodwaters that flow down steep rivers will contain large quantities of sediment, and wash away houses and buildings by their huge energy like debris flows, and cause destructive damage. Frequent, large-scale floods and increased sediment run-off may destabilize river beds, causing the destruction of structures, such as bridges, and levee breaches, which may lead to more floodings.

Inundation caused by levee breaches will spread over the lower reaches after inflicting different types of damage on locally important cities, industrial parks, rice paddies, and agricultural fields producing local specialties. When the revitalization of local economies is one of today’s important tasks in Japan, floods reduce the competitiveness and vitality of local communities and seriously affect local economies.

3. Lower basin areas and coastal zones

In lower basin areas and coastal zones, where low lands and areas below sea level spread, intensified rainfall, higher short-time rainfall intensity, rising sea level, intensified typhoons, and flooding waters from the middle reaches are likely to cause more frequent inundation and flooding events due to levee breaches. Advanced urbanization in low lands and below-sea-level areas has caused larger discharge, making proper draining difficult. Thus, inundation by river and landside waters due to flood, sediment-related, storm-surge and other disasters are likely to prolong over a long period of time. Particularly in below-sea-level areas along the three major bays in Japan (Tokyo, Ise and Osaka Bays), the area and population below the mean sea level

would increase by about 50% if the mean sea level were to rise by 59 cm, which is the extremist projection value in the IPCC 4th Assessment Report. Greater damage by storm surges is projected in this case.

In many cases, lower basin areas and coastal zones are over populated and have accumulation of property. Particularly because the three megacities serve as the centers of social and economic activities, flood, sediment-related, storm-surge and other disasters will affect not only the lives and property of people but also cause governmental functions to be paralyzed and international competitiveness to drop.

Also, coastal erosion is already advancing in some coastal zones due to decrease in sediment supply. Further sea level rise and intensified typhoons may accelerate coastal erosion and cause sand beaches to disappear. A sea level rise of 30 cm is projected to cause about 60% of all sand beaches in Japan to disappear.

Impacts of sea level rise and intensified typhoons may constitute huge hindrances to national land protection.

III. Basic directions of adaptation strategies

III-1. Trends of adaptation strategies in foreign countries

In October 2007, the European Union (EU) announced the Directive on the Assessment and Management of Flood Risks. The directive requires the member nations to assess flood risks based on available knowledge including the impacts of climate change on flood occurrence. It also requires them to prepare flood hazard maps and flood risk maps based on multiple annual probabilities of exceedance. The directive also calls for consideration of impacts of climate change when preparing and revising flood risk management plans.

In England, the flood safety level against storm surges are projected to drop from once every 1,000 years to once every 100 years by sea level rise due to recent climate change and rapid housing land development. Thus, the Thames Estuary 2100 (TE 2100), which is a flood risk management plan in England, is being planned as well as improvement of Thames tide embankment.

In the Netherlands' flood risk management plan called "Room for the River," a total of approximately 7,000 ha are to be secured for retarding areas to cope with increase in discharge of the Rhine. The Maeslant Barrier along the Lek River is designed to cope with sea level rise in 50 years. Other storm surge barriers are also designed to cope with sea level rise during their service periods.

In May 2006, the Organization for Economic Cooperation and Development (OECD) summarized the progress regarding adaptation strategies for climate change in developed countries. Adaptation strategies are also being promoted and reviewed in European nations, such as Germany and France, the US, and Australia.

On the other hand, Asian nations other than Japan are Non-Annex I

Parties under the Framework Convention on Climate Change¹⁹, and only few have developed adaptation strategies in their national projects mainly due to insufficient adaptation technologies and funds. Of the few, Korea has developed national strategies for water security and systems for assessing impacts on water resources. For the least developing nations such as Bangladesh, Bhutan, and Cambodia, the National Adaptation Programme of Action (NAPA) is being implemented with the financial assistance of the Global Environmental Facility (GEF) and the cooperation of the United Nations Environment Program (UNEP) and the World Bank.

¹⁹ Non-Annex I Parties under the Framework Convention on Climate Change: A group of 148 developing countries for which no numerical goals to reduce greenhouse gas emissions are set by the Kyoto Protocol under the UN Framework Convention on Climate Change (UNFCCC). Annex I Parties are a group of countries listed in the UNFCCC Annex I and have quantitative obligations as described in the annex of the Kyoto Protocol. Annex I Parties include developed countries and transition economies, such as former Soviet Union and Eastern European countries.

III-2. Basic directions of adaptation strategies

1. Coping with intensified external forces

(Shifts in flood control policies)

Considering future precipitation increase, design flood peak discharges need to be further raised if present flood safety levels are to be maintained. However, it is sometimes extremely difficult to construct structures, including river-improvement and flood-control structures, which can accommodate such increased discharges, because of social and other constraints. Also, construction of structures usually takes a considerably long period of time before completion.

Keeping present design discharges would result in severe drops in flood safety level in the future, and the risks of floodings and inundations may increase.

To solve these issues, the increment in external forces caused by climate change should be clearly defined in coping strategies against floods that exceed current design scales or structure capacities during improvement (hereinafter referred to as the “excess floods”).

Therefore, traditional “flood control policies to secure safety at the river scale” through river improvement and the construction of flood control structures to meet target discharge levels for past and current river projects should be shifted to “flood control policies to secure safety at the basin scale” through preparation for possible increase in excess floods. Also, though flexible response to excess floods will be necessary for the time being, new frameworks should be drafted based on the understanding that climate change due to global warming is a common phenomenon.

(Enhancing measures against intensified debris flows)

In addition to measures against intensified debris flows, measures

should also be developed and implemented to control sediment in flood waters and mitigate the impacts of accumulating sediment.

Comprehensive sediment control measures for areas extending from mountains to coasts should be enhanced to control and mitigate the impacts of increased sediment run-off, along with disaster mitigation measures.

(Staged measures against storm surges)

In order to minimize the frequency of flooding which is likely to increase by sea level rise and intensified typhoons, concrete storm surge barriers should be rebuilt higher to enhance their protection capacities against intensified external forces, especially at a time of renewal.

In practice, barrier heights should be raised in stages.

- First stage: Barriers should be raised for the height equivalent to the current sea level rise.
- Second stage: Barriers should be raised for the height equivalent to the past sea level rise as well as predicted or extrapolation future rise during the service life of the barriers.
- Third stage: Heights of storm surges caused by intensified typhoons should be considered together with the rises determined in the second stage.

The second- and third-stage measures should be taken earlier depending on importance of hinterlands. The concept of structure design should also be revised so as to cope with changes caused by sea level rise in external forces acting on the structures.

2. Defining clear goals -- Aiming for “Zero victims” --

Since it is difficult to totally protect everything from flood, sediment-related, storm-surge and other disasters, which are likely to be intensified by climate change, adaptation strategies for climate

change need to be developed aiming for “zero victims.” In areas, such as the Tokyo metropolitan area, where key functions are concentrated, it is also important to minimize damage by prioritizing the protection of state functions from paralysis.

Multiple disasters should be taken into account since Japan is prone to earthquakes and volcanic activities. An earthquake may trigger a landslide after a storm that increases the groundwater stage and soil moisture.

Adaptation strategies should also be designed to form a national land where society and nature coexist in harmony. Adaptation strategies should ensure disaster mitigation and sound livelihood.

3. Basic contents of adaptation strategies

Possible impacts of climate change on each basin need to be notified to the public and related organizations when considering adaptation strategies for climate change. The national government should take the initiative in developing coping strategies at the basin level, including role-sharing among related organizations.

Basin-based adaptation strategies may require the restructuring of the relationship between rivers and basin communities. Thus, the development of such strategies needs to be carefully carried out while forming consensus by adequately sharing information with the public and related organizations about the relationship among society, nature and safety in a basin.

The development of adaptation strategies should start with determining protection levels using structures against increasing external forces. Then, to what degree each basin will cope with external forces exceeding the capacities of the present structures (hereinafter referred to as the “excessive force”) in the basin should be determined. Adaptation strategies for minimizing damage should be

drawn up based on that degree. For floods, adaptation scenarios appropriate for different flooding patterns should be drafted. More specifically, some adaptation strategies can be devised with emphasis on the revision and regulation of land use in basin communities, while other prioritizing risk management.

The following (1)-(3) describe the basic concepts of adaptation strategies with different emphases.

(1) Adaptation strategies with emphasis on the revision and regulation of land use in basin communities

Land use and ways of living have altered along with changes in social conditions, such as population decrease and aging. It is important for future communities to adopt systems for restructuring themselves according to different needs and conditions. Conventionally, society in general has been structured based largely on economic efficiency and convenience; however, a new viewpoint of accepting water-related disasters as part of our life is necessary to restructure basin communities.

1) Revising land use and ways of living based on changes in social conditions

Land use and ways of living should be revised from viewpoints of safety and security to protect lives and property from disasters and mitigate serious damage.

Basin community development should also promote the storage and infiltration facilities.

2) Developing communities to adapt to inundation

Community development should include strategies for low susceptibility in terms of lives and property during floodings which are likely to increase in frequency and scale. To this end,

water retarding basins, secondary levees and ring levees should be reassessed for their effectiveness as protection based on current land use in each community. Also, new such structures should be effectively implemented, if necessary, and managed along with rivers.

(2) Adaptation strategies with emphasis on crisis management

Intensive facility construction and improvement alone will not ensure the complete protection from flood, sediment-related, storm-surge and other disasters. Also, it is often difficult to respond well to sudden, large-scale disasters whereas it is relatively easy to take flexible measures for progressive phenomena, such as sea level rise. However, preparation for such sudden disasters is still necessary to respond quickly to possible situations. Thus, measures against large-scale disasters with emphasis on crisis management need to be implemented together with preventive structure/facility construction.

1) Developing systems for responding to large-scale disasters

Preparedness for large-scale disasters should be substantially promoted. The national government should enhance wide-area disaster relief systems and organize trans-regional disaster mitigation networks so as to better manage disaster risks and respond to actual disasters. Also, the national government and local bodies should cooperate and implement measures for different disaster cases: urgent measures in case of levee break and inundation, measures for floodwater and its drainage in flood-prone areas, and quick, appropriate response measures during large-scale sediment-related disasters.

2) Promoting non-structural measures based on new scenarios

Non-structural measures should also be promoted along with structural measures. Communication, flood fighting, evacuation, rescue efforts, restoration and rehabilitation should be thoroughly discussed based on not only conventional scenarios but also new scenarios which consider changes in frequency and timing of external forces.

Residents should be well informed of disaster mitigation and able to share necessary information with public offices through two-way communication. Also, efforts should be made to improve local disaster preparedness for water-related disasters to mitigate disaster impacts through communal cooperation.

(3) Adaptation strategies with emphasis on structures

Structures prevent external forces from causing damage, when such forces are within their design capacities, allowing people to engage in regular social and economical activities. It is important to keep improving structural capacities as much as possible.

From a viewpoint of protecting lives and property, preventing and minimizing damage during disasters by constructing and improving structures will continue to be important.

1) Maintaining the reliability of structures against changes in external forces

Measures should be implemented for maintaining the reliability and improving the quality of structures against projected changes in external forces by inspecting and assessing the structures.

2) Full utilization of existing structures and prolonging their service life

Taking full advantage of social infrastructures that have been developed so far, existing structures should be made full use of by promoting effective, multi-purpose use, by prolonging their service life, and by increasing efficiency through reorganization and the revision of their operation.

Specifically, storm surge structures in Japan are increasingly degraded due to aging. They were constructed after the devastating experience with the Ise-wan Typhoon, which hit the

country about 50 years ago and became the standard external force to design storm surge structures. The structures need proper improvement or reconstruction. In addition, many of the flood control structures built in 1960s and 1970s will soon need repairing or reconstruction as well. They were intensively constructed during those periods to prevent frequent floods due to rapid basin urbanization.

Under those circumstances, preventive and conservative management is necessary for prolonging the service periods of such structures. Concurrently, measures for adapting to changes in external forces due to climate change need to be devised and implemented. It will be effective and efficient to implement such measures at the same time when restoring disaster-affected structures.

3) Constructing new structures

New structures should also be steadily constructed as well as thoroughly using existing structures from social, environmental, economic and technical points of view.

4. Issues for implementing adaptation measures

The strategies to ensure basin safety based on the scale of design external forces for structure construction as well as excess external forces should be first reviewed before developing adaptation strategies.

Assessment of external forces and risks which are the basis of designing adaptation measures is a responsibility of the Ministry of Land, Infrastructure, Transport and Tourism. Besides taking actions by the entire national government and building a partnership among related ministries and agencies, a cooperation system among industry, academia and government should be formed to create a framework for collecting new ideas.

Monitoring of increasing external forces should also be enhanced.

IV. Implementation of adaptation measures

1. Basic implementation strategies

Since flood control should be executed along with long-range plans, changes in external forces should be appropriately estimated, and adaptation measures to climate change should be incorporated in currently on-going flood control policies.

On such an assumption, adaptation measures should be implemented based on the following basic strategies.

(1) Governmental efforts

Considering the importance of adaptation, the entire government should promote the implementation of adaptation measures.

(2) Promotion of cooperative work with the public

Cooperative work with the public is indispensable to planning and implementing adaptation measures. Efforts should be made at every possible opportunity to gain better, wider public understanding of the impacts of climate change on flood, sediment-related, storm-surge and other disasters, as well as the national land and society.

(3) Priority investment in preventive measures

While funds are limited, investment priority should be placed on preventive measures for certain structures that are predicted to become degraded and to protect areas where population, property and central functions are concentrated.

(4) Clear prioritization

To strengthen adaptation measures to climate change within limited funds, priority measures and components should be carefully selected in addition to comprehensive sets of measures.

(5) Preparation of road maps

Clear road maps for different time frames should be drawn up from short- and middle-range viewpoints of five and ten years and also

from a long-range viewpoint for national land planning.

(6) Adoption of a flexible approach

Adaptation measures should be designed and implemented in a flexible manner in which prediction scenarios for the measures will be continuously revised in accord with accumulation of observational data and knowledge because climate change prediction always contains some uncertainties.

(7) Cooperation with related organizations

In basins for which adaptation measures are comprehensively planned, river administrators alone cannot carry out necessary tasks in many cases. Thus, it is indispensable to gain cooperation from residents and related organizations as well as to conduct the tasks in collaboration with them.

To this end, it is important that all parties should raise issues and propose ideas for better community development.

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

New technologies for impact assessment of and adaptation to climate change should be developed and actively used under collaboration among industry, academia and government. Japan should demonstrate strong leadership in this field and try to contribute to the international community by actively transferring the experiences, policies and technologies of Japan to support developing countries.

(9) Promotion of research and application of their results to flood control plans

Research on flood, sediment-related, storm-surge and other disasters that may accompany climate change should be promoted jointly with universities and research institutes, and the results

should be reflected in flood control plans.

2. Procedure for the implementation of adaptation measures

The issues for implementing adaptation measures (III-2.4) should be studied during the first short-range period, which is about five years until the IPCC Fifth Assessment Report is published as a summary of a next set of new knowledge. Existing measures which are considered to be important adaptation measures should be immediately implemented with special emphasis.

The adaptation measures in the first period should be reviewed and prioritized based on the review results for the implementation during the subsequent period (second period). Adaptation strategies which are newly recognized as effective and efficient should be intensively implemented. Flood control policies and adaptation strategies selected for implementation should be reflected in the Basic River Improvement Master Plans and River Improvement Strategic Plans as well as in national land planning, which illustrates future visions for national land development and community development.

After the second period onwards, it is important that adaptation measures should be designed based on changes in social conditions, a wide range of accumulated knowledge, and changes in condition settings accompanying accumulation of monitored data. These measures should be implemented step by step.

For international contribution, Japan should address to world leaders the importance of adaptation strategies as most important national policies as well as the need of international cooperation. It is also important to assist other countries in the design and implementation of adaptation strategies as well as in the prediction of climate changes in the Asia-Pacific region using global models as well as resultant impacts on society and national lands.

Technical issues involved in designing and implementing specific adaptation measures will be summarized separately.

Conclusions

The IPCC 4th Assessment Report was published, showing more realistic impacts of global warming. Also in Japan, adaptation measures to climate change caused by global warming have been reviewed in various fields. The subcommittee is set to consider the impacts on the national land and society of intensified flood, sediment-related, storm-surge, drought and other disasters, and also to discuss the basic directions and practical adaptation measures for avoiding destructive damage due to such disasters.

The subcommittee has shown the basic directions of necessary adaptation strategies based on projected increases in external forces and impacts on the national land and society, although at the moment there is some degree of uncertainty in the global warming scenarios, future social conditions and simulations of climate change. Climate change may seriously affect the land of Japan, which is still vulnerable in terms of flood control, water use and river environment, but we must fight against the impacts by taking adaptation measures that involve the reformation of social structure (e.g. basin-based adaptation measures) as well as through the full use of existing structures.

However, adaptation measures that involve changes in social structure cannot be fully executed by river administration alone. They need to be promoted by the entire government and related ministries with understanding and cooperation of citizens and related organizations.

This interim report summarizes discussions made by the subcommittee so far to contribute to full-scale discussion of practical adaptation measures and collect a broad range of opinions on social structures and basic strategies for adaptation measures.

From this time forward, opinions and ideas are expected to be extensively exchanged with the Central Disaster Prevention Council and subcommittees of the Panel on Infrastructure Development and the

National Land Development Council, so that it will be possible to discuss more practical adaptation strategies for implementation.

In December 2007, the first Asia-Pacific Water Summit was held in Kyushu, Japan. The participating countries and groups agreed that water issues were the highest priority issues to be solved and that urgent, effective action needs to be taken to mitigate damage by water-related disasters, such as floods and droughts. They also shared the common recognition on the importance of adaptation. As a host country for the G8 Summit in Toyako, Hokkaido in 2008, Japan should be able to send pertinent messages in relation to adaptation. To this end, it is important to conclude a further detailed report by the coming summit meeting.

The subcommittee will discuss specific adaptation strategies, including those for droughts, by studying opinions to the interim report and will conclude the final report to submit to the national government.

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River Sector Committee,
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