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Fundamental Characteristics of Flood Risk in Japan's Urban Areas

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1 Introduction

Flood risk is diverse and complex. Risk-related phenomena such as flood-inducing precipitation, runoff generation and concentration, downstream flood wave propagation, flooding, and flood damage are changing over time and vary from region to region under the influence of natural conditions, human activities, and Japan's disaster culture. In Japan, the loss of life and national economic losses caused by flooding have drastically declined over the last 60 years. However, new flood risks are emerging in urban areas, including more potential for flooding, more exposure to flood risk, and new forms of damage.

For example, in Japan, recent flood disasters resulting from embankment failures have led to catastrophic damage and consequences. The general economic loss caused by the 2000 Tokai flood disaster, in which the metropolitan areas of Nagoya were flooded, was the worst in 40 years. Furthermore, embankment failures led to serious damage in a number of provincial urban areas in 2004, with the drowning of elderly people a major issue in Niigata. New risks have also been identified in urban areas. In 1999, the underground shopping mall at Hakata Station in Fukuoka, Japan's sixth largest city, was flooded, and one life was lost in a building basement. River environments have undergone drastic changes over the past 100 years as rivers are forced into artificial channels, leaving them with less natural, more artificial environments. Moreover, disaster-prevention awareness and activities in local communities has been decreasing.

Takahashi (1964, 1971) examined flooding events in Japan and showed that floods were not a purely natural phenomenon and that social conditions played an important role that varied from region to region and from time to time. Takahashi (1964) illustrated the structure of modern flood disasters up to the 1960s, just the initial stage of Japanese experience in a period of high economic growth. He also pointed out that the peak flood discharge of rivers had increased as a result of river improvement projects. Today, more than 40 years after the report, flood disasters have taken on a new look and flood risk has become more diverse and complex.

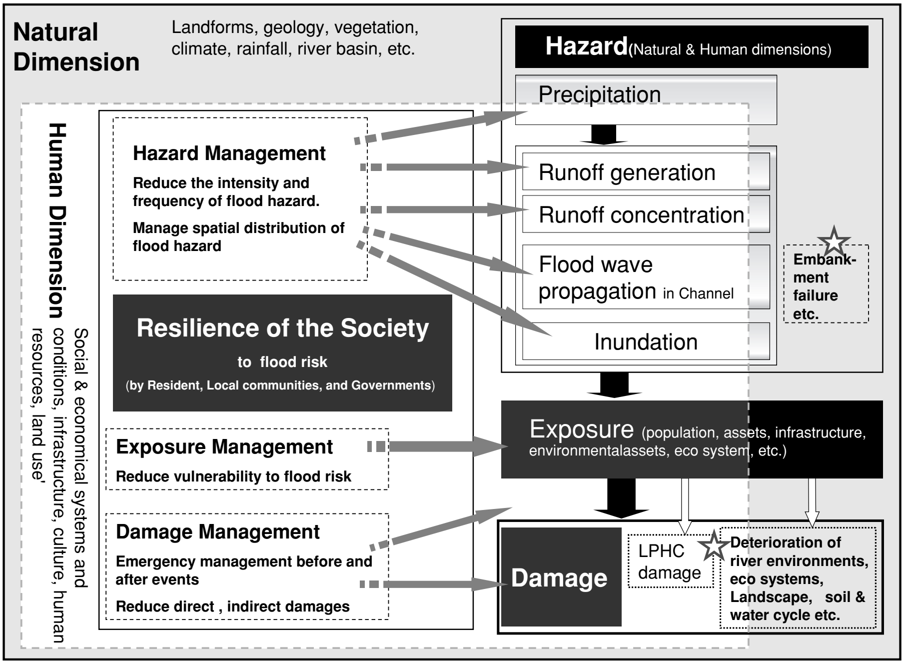

Fig. 1. Causal structure of flood risk.

This paper describes the recent structural changes in flood risk characteristics for urban areas in Japan using the results of flood-disaster investigations into the 2000 Tokai urban flood disaster which occurred in one of the metropolitan areas in Japan and the 2004 Niigata flood disaster which occurred in provincial urban areas (Sato, 2002; Sato *et al.*, 2006). The paper reviews existing knowledge in the fields of geography and river engineering and uses the causal structure of flood risk to describe the characteristics of flood risk.

2 Causal Structure of Flood Risk

The causal structure of flood risk is shown in Fig. 1. Flood risk has four components: Hazard, Exposure, Damage, and Social Resilience to flood risk. All four components are subject to both natural and artificial environments that vary over time as social and economic conditions and human activities evolved. The components are defined as follows;

1) Hazard is an external natural force that has the potential to cause flood damage. Precipitation is the primary external factor. The scale and pat-

tern of precipitation and its distribution in time and space in a basin are major factors that determine the magnitude and characteristics of the flood hazard. The flood hazard is transformed, as shown at the far right of Fig. 1, as precipitation runoff concentrates in river channels and flood waves propagate down the river channels. Ultimately, inundation occurs. Because these phenomena occur on or near the surface of the Earth, where human activities take place, flood hazards have local characteristics that are affected by geology, topography, vegetation, and land use in the river basin.

2) Exposure refers to the socio-cultural units that are exposed to flooding, such as populations, assets, environmental resources, biological resources, lifelines, social functions, etc.

3) Damage is the deterioration or loss of functionality of units exposed to flooding. This includes not only direct damage but also indirect damage to the social, economic, and natural environments.

4) Social Resilience to flood risks is the ability of society to withstand the hazard as a result of efforts in disaster risk management.

3 Characteristics of the Recent Flood Risk in Japan

3.1 Flood hazards

One of the characteristics of flood risk in Japan is the significant qualitative and quantitative changes in the flood hazard resulting from human activities such as flood control measures, a trend that grows stronger during periods of high economic growth. As a result, the frequency and intensity of floods has drastically decreased, increasing the possibility and complexity of catastrophic flooding and creating a cascading series of flood hazards in urban areas.

3.1.1 Outline of changes in flood hazards

Flooding can be effectively controlled using Large-Scale Flood Control Structures (LFCS) such as high continuous embankments along rivers, as well as dams, pumping stations, etc. These LFCS have been applied to a remarkable degree throughout the length and breadth of Japan for 100 years along both large and small rivers. As a result, the intensity and frequency of floods, in terms of spatial and temporal distributions, have drastically decreased in Japan over time. Alluvial lowlands are no longer constantly vulnerable to flooding.

However, by improving and shortening the river channels, constructing high and continuous embankments to keep flood waters in river channels, and expanding storm-water drainage systems, LFCS have increased a potential of creating new flood hazards. Namely, LFCS change the way flood waves propagate in rivers, shortening the time-lag between the rainfall and the peak discharge, thereby increasing the flood discharge flowing down the channels (Takahashi, 1971; Sato, 1998). Moreover, the volume of flood runoff has increased as a result of the loss of water detention capacity of urban catchments. These days, a particular quantity and pattern of rainfall results in a flood discharge of greater volume and with a higher peak discharge than ever before. Moreover, the number of heavy rainfalls, the primary external force of a flood hazard, has been increasing in urban areas in Japan, according to statistics for Japan (JMA, 2005). If this trend continues, it might become a major factor in increasing the flood risk in urban areas.

In addition, another factor that increases flood risk is occurring in the floodplains. This factor is ground subsidence and is mainly caused by groundwater pumping. This has increased the area, depth, and duration of floods. Sometimes subsidence has led to the sinking of river embankments.

3.1.2 Increasing the possibility of catastrophic flooding

The development of LFCS has notably decreased the frequency and intensity of flooding by cutting off the process of hazard transformation, as shown on the right-hand side of Fig. 1. However, recent flood disasters in Japan indicate a different scenario for catastrophic flooding: embankment failure resulting from precipitation exceeding the level specified in the design. In other words, extensive LFCS construction in Japan has increased the possibility of catastrophic flooding.

The typical process of how catastrophic flood hazards escalate is clear from the 2004 Niigata flood disasters. The Ikarashi River and Kariyata River are branches of the Shinano River, the longest river in Japan. The catchments are 239.8 km^2 for the Kariyata River and 310.1 km^2 for the Ikarashi River. The following is a description of the process by which the flood hazards escalated, leading to the 2004 Niigata flood disaster.

1) Escalation of the flood hazard potential as a result of LFCS construction

i) Increases in embankment heights and channel capacity The channel and embankments of the Ikarashi River have been repeatedly improved in response to severe floods. A great flood in 1873 triggered the start of river improvement works in 1876. In 1925, the other severe flooding resulted in additional work to increase the flood flow capacity of the channel, which reached 1,120 m^3/sec in 1937. The capacity was further increased to 1,600 m^3/sec after a flood in 1961. After yet another flood in 1969, the capacity was increased to 2,400 m^3/sec. In addition, an upstream dam increased the design flood flow of the channel to 3,600 m^3/sec. Thus, the river capacity has risen continually through channel and embankment work after major disasters. The peak flood discharge currently is 2.14 times larger than it was 70 years ago. In a similar manner, the flood capacity of the Kariyata River channel has risen from 650 m^3/sec in 1920 to 950 m^3/sec, 1,050 m^3/sec, and finally 1,550 m^3/sec in 1969. With this capacity, it is designed to accommodate the type of floods that occur only once in a century. The frequency and intensity of flooding has drastically decreased on the floodplains, but the embankments have risen in height and, with heavy precipitation, a huge discharge flows down the river channels (Sato, 2006). Thus, by repeatedly reducing flooding, this embankment work has ironically or necessarily increased the potential for catastrophic flooding of due to possible embankment failure.

ii) Embankment failures caused by rainfall exceeding design specification During the 2004 floods, heavy rainfall induced a peak flood discharge of 1,900–2,000 m^3/sec in the Ikarashi River and 1,700 m^3/sec in the Kariyata River, respectively, exceeding the design discharge of the river channel and causing embankment overflow. The embankment had been eroded and eventually collapsed. The level of precipitation contributing to the peak discharge of the two rivers occurs only once every 500 years (JSCE, 2004). For example, 267 mm of rainfall fell in six hours. In twenty-four hours, the amount reached 422 mm, far above the level specified in the design of the LFCS.

iii) Increased force and volume of floodwaters Floodwaters generally flow very slowly over an alluvial plain that has a very gentle slope of 0.7–0.8/10,000, as in the case of the floodplains of the Ikarashi River and Kariyata River. However, the embankment failure increased the force of the floodwaters because of the big difference in the hydraulic head between the level of water in the river channel (14.7 m) and that of the floodplain (9.46 m) and the very short collapse time (with 10 m of the embankment collapsing in just 5 min). In the end, the breach was 50 m wide (Niigata Prefecture, 2005). A huge and rapid flood flow washed away a temple near the collapse site, and houses within 150 m from the site were completely destroyed.

The estimated volume of floodwater released by embankment failures along the Ikarashi River was 13.93 million m^3. Along the Kariyata River, it was 8.80 million m^3. These volumes are 40 to 50 times larger then the estimated volumes of water that simply overflowed the embankments of these two rivers (0.34 million m^3 and 0.36 million m^3, respectively). The observed result in both cases was much deeper and more extensive flooding (Sato *et al.*,

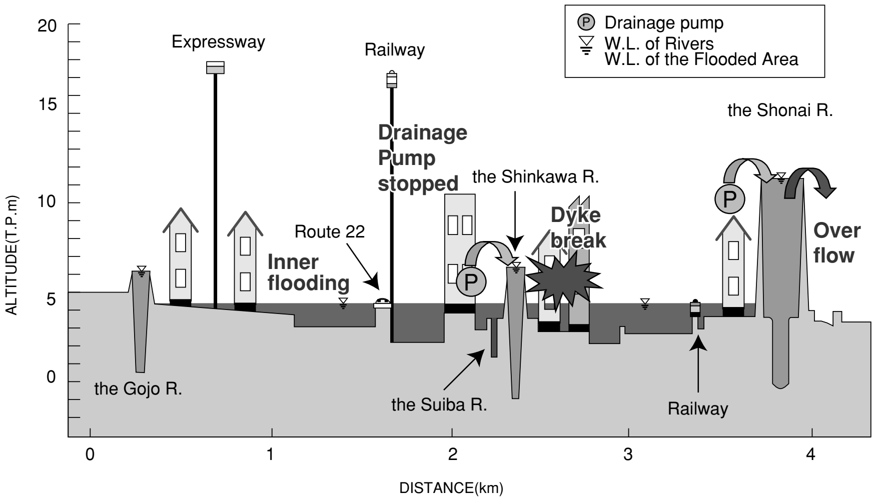

Fig. 2. Topographical cross section of the 2000 Tokai floods disaster area Increase of flood damages by different causes in the 2000 Tokai-Flood (MLIT, 2000).

2006).

2) Increased depth of flooding by development of floodplain

Another factor that contributed to the intensity of the flooding was development of the floodplain. One example is the development of the narrow valley plain on the left side of the Kariyata River in Mitsuke City. River improvement works had straightened the meandering channel but narrowed the width of the valley from 400–500 m to 300 m. Housing development in the narrow valley plain accompanied the work. The floodwaters flowing from the embankment breach site were dammed by houses, factories and earth mounds, which deepened the floodwaters, allowing them to reach older settlements on the higher terraces that used to be relatively safe from flooding (Sato *et al.*, 2006).

3.1.3 Increase in complexity, and cascade effect of flood hazards

Fig. 2 shows a typical river system in an urban area with considerably developed LFCS type river improvements. This example is a topographical cross-section of the 2000 Tokai flood disaster area, the Nagoya metropolitan area. Flooding caused by large rivers had been reduced. On the other hand, rapid urbanization led to increases in flooding by small and medium-size rivers. This led to various management bodies making improvements to urban rivers of various sizes.

Fig. 2 shows how rivers with different runoff characteristics form an interacting network, with sizes ranging from rainwater drainage systems to large-scale rivers. This means that a variety of hazards arise in a cascading manner in any one area, such as from inner flooding, flooding caused by small and medium-size rivers, and catastrophic flooding triggered by embankment failure on a large river. Furthermore, the water levels of rivers affect each other on an alluvial plain with a low gradient, strengthening the potential of the cascade effect. As shown in Fig. 2, if the Shonai River (a large river) or the Shin River (a medium-size river) becomes full, the drainage pumps must be halted, which intensifies the flooding on the floodplain. Water levels in tributaries such as the Gojo River and Suiba River (both small rivers) are affected by the backwaters from the Shin River. Moreover, there is no integrated management system among these rivers. Improvement plans for each are designed on a different scale, and they are managed by different management entities. For example, large rivers are managed by the central government, which plans for large floods that occur once in 200 years. Medium-sized rivers are managed by the prefectural office, which designs plans to handle floods that may occur once every ten to fifty years. Small rivers and urban storm drains are managed by the city office, which designs plans to handle floods that may occur once every ten years.

Heavy rainfall in excess of the levels specified in the design of the LFCS measures triggered the 2000 Tokai flood disaster. For example, the 97 mm of precipitation recorded in 60 min. at the Nagoya meteorological observatory occurs once every 110 years and exceeds the design specifications of the storm-water drain system and the small river improvement works. A 24-hour precipitation of 534.5 mm was recorded. Such precipitation occurs once every 350 years and exceeded the design specifications for improvement works on medium-size and large rivers.

Fig. 3 illustrates the cascade effect of flood hazards in the 2000 Tokai flood disaster areas. The inundated area and the area of economic loss increased as damage and inundation accumulated from different hazard sources during the event (Sato, 2002). First, inland flooding was caused by an overflowing storm-water drain system that had the smallest catchment. The flooding occurred on September 11 at around 18:00, immediately after 97 mm of precipitation in 60 minutes. The floodwaters rose over the top of the embankments of the Yamazaki River, a small river. The water level then rose to the high-water level specified in the design for medium-size rivers, at which point, pumping was stopped to prevent overflowing of the embankments. Then overflow caused the Shin River, a medium-size river, to fail its embankment, resulting in severe damage. Finally the floodwaters began to overflow at some part

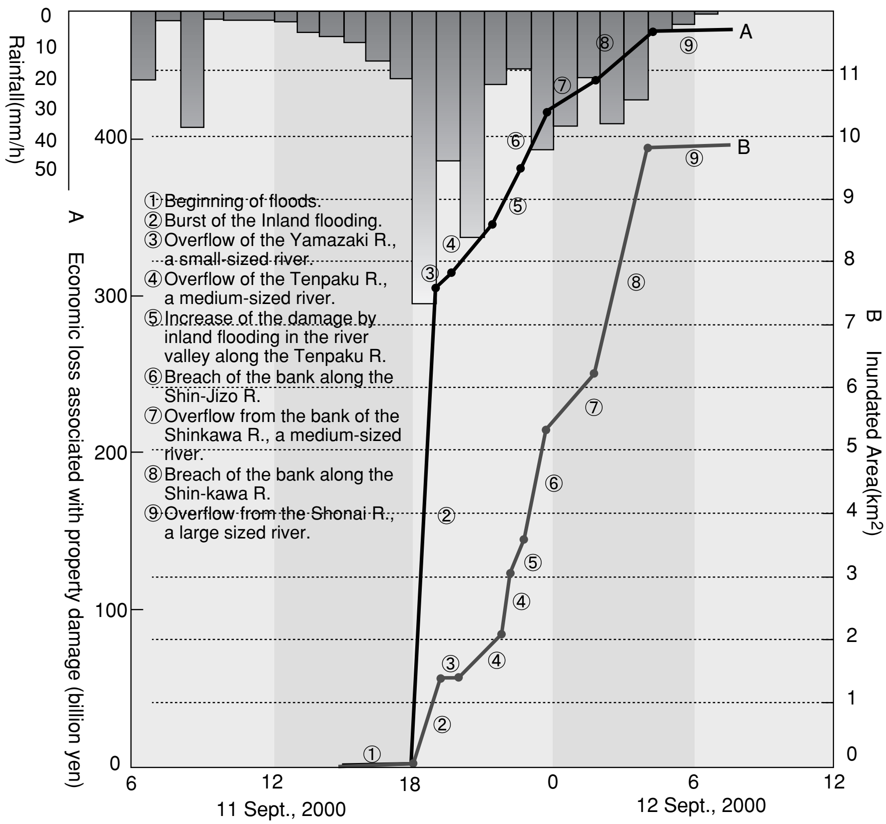

Fig. 3. Increase of the damage caused by flooding of different rivers in 2000 Tokai Flood (T. Sato, 2002).

of the embankments of the Shonai River, the largest river, on September 12 at around 4:30, approximately ten hours after the floodplain began flooding. Sandbagging prevented overflowing, and the embankment did not fail.

3.2 Change in exposure and new type of damage

The damage caused by flooding has drastically changed both quantitatively and qualitatively through urbanization and the more extensive land-use in urban areas. In these areas, the potential for damage has increased along with the possibility of catastrophic damage from flooding. On the other hand, a new type of flood damage has emerged.

3.2.1 Catastrophic damage caused by flooding

Accelerated economic growth and innovation in all sectors of the social infrastructure in the period from the 1960s through the 1980s brought about

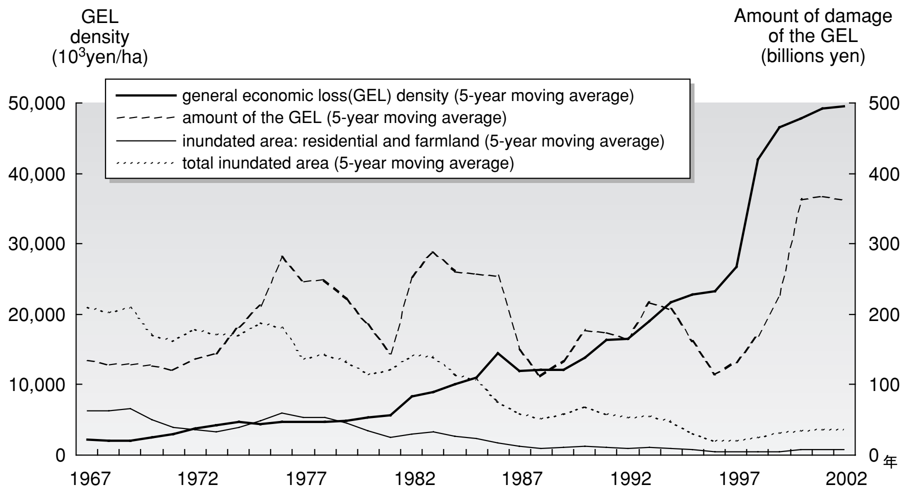

Fig. 4. Trend of General Economic loss density in Japan (MLIT, 2001).

rapid population growth in Japan's metropolitan areas. Without effective laws governing land use, populations and assets became concentrated in flood-prone, low-lying areas that had previously been vacant or used as paddy fields. Currently, 49% of the Japan's total population and 75% of the country's total assets are concentrated in alluvial lowlands, which account for 10% of the land in Japan.

Fig. 4 shows the trend in the totally inundated areas in residential districts, the economic loss of general assets, and the density of economic loss over the previous 40 years. Numerous river improvements have effectively reduced the total number of inundated areas. There has been no decrease, however, in the general economic loss. The solid line indicates that the density of general economic loss per hectare of inundated land in residential districts has been rising in recent years, demonstrating the increasing potential for damage discussed in the previous section.

Exposure to flood hazards has changed drastically through the concentration of populations and assets. Though very rare, catastrophic embankment failures do happen, but the resulting damage can be tremendous, especially in urban areas. This type of disaster is called a Low Probability but High Consequences (LPHC) event. In fact, severe flood disasters caused by embankment failures recently have been common in Japan. The 2000 Tokai flood disaster is an example of how damage increases as a consequence of an LPHC event in urban areas. The embankment failure of the Shin River, a medium-size river, resulted in considerable damage to Nagoya's metropolitan areas and caused the worst general economic loss in 40 years. The area that flooded due to the embankment failure accounted for only 16% of the total flooded area, but the value of the damage was 56% of the total. The economic loss to general assets due to inner flooding of the floodplain was 9 million yen/hectare. On the other hand, the loss due to flooding caused by embankment failures was 778 million yen/hectare.

3.2.2 New types of damage

Social changes have also drastically affected exposure to flood hazards, and new types of flood risks are appearing. Some examples from recent flood disaster events are given below.

1) With changes in the social structure of post-industrial society, urban space is becoming denser and more complex. The urban facilities, information systems, and networks that are now being built are particularly vulnerable to flood damage. Recent urban floods are examples of a new type of disaster that causes a new type of damage in urban areas. For example, in the 2000 Tokai flood, subway lines and stations, building basements, and underground machine rooms for huge storm water pools were inundated. ATM machines were also damaged. Around 100,000 cars were damaged and the insured loss was a record 54.5 billion yen for 58,000 cars. In 1999 and 2002, floodwaters from small and medium-size rivers in the Fukuoka metropolitan area damaged underground shopping malls and the basements of buildings around Hakata Station.

2) Japan has a rapidly aging population. Many elderly people have difficulty to respond to emergencies due to disabilities, limited access to information, etc. In the 2004 Niigata flood disaster, many elderly people drowned in Sanjo City.

3) LFCS measures have created complicated networks of highly artificial river channels that adversely impact the natural environment and wildlife habitats. Until the 1970s, the primary concern was reducing flooding and securing adequate water supplies for industry and urban residents. Natural river courses have been converted into man-made channels for discharging floodwaters. With the advent of more diverse social values, including greater global environment awareness, environmental deterioration, such as the degradation of rivers, landscapes, and

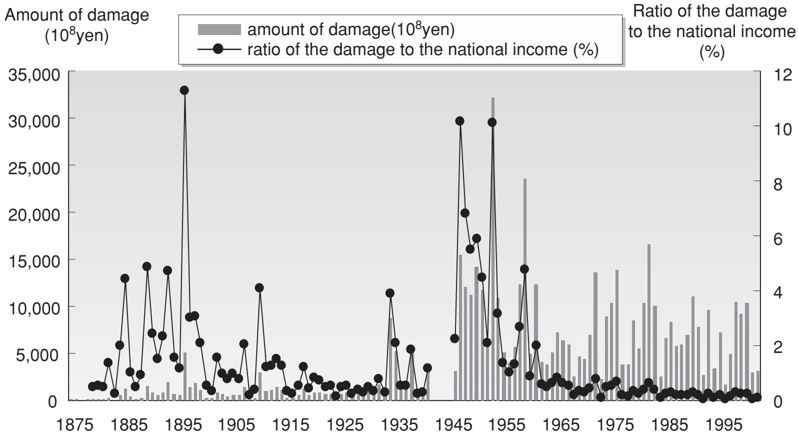

Fig. 5. Trend of flood damage in Japan (MLIT, 2001).

wildlife habitats, is viewed as a type of damage typical in the late 1970s (MILIT, 2004).

4) Since the early 1960s, high economic growth has been accompanied by degradation of the water cycle and soil resulting from the construction of flood control and debris dams and the removal of gravel. Coastal erosion is another problem everywhere in Japan. For example, decreasing silt supplies at the mouth of the Shinanogawa, caused by the construction of a flood diversion channel known as "Ookozu-Bunsui," has led to significant erosion of the coastline west of the main channel. The shoreline eroded 250 m in the 25-year period from 1921 to 1946. Even after restoration work was completed, erosion continued since then (Sunamura, 1996).

3.3 LPHC type flood risk and resilience of society to flood risks

Recent flood disasters show that flood risk in Japan is characterized by LPHC type risk created by natural and artificial environments. In this section, social resilience to flood risks is described, focusing on LPHC type flood risk.

3.3.1 Hazard mnagement

The resilience of society to flood risks refers to our capability to cope with flood risk by means of integrated management of hazards, exposure, and damage. As shown in Table 1, residents, local communities, and governments may reduce the flood risk by implementing measures that prevent certain events from occurring. Such measures include (1) reducing the runoff in catchments, the runoff concentration into river channels, flood-wave propagation downstream, and inundation; (2) reducing exposure vulnerability; and (3) Mitigating or compensating damage.

1) Drastically decreased frequency and intensity of flooding

In Japan, ever since the central government assumed responsibility for flood control on large rivers in 1897, there has been disproportionate emphasis on government-led preventive measures to use LFCS to control flooding. Fig. 5 shows the value of flood damage and its ratio to national income over the period of 120 years since the Meiji era. Major flood disasters with more than 1,000 casualties continued to occur until after the Second World War. Intensive use of LFCS coincided with the growth of the economy. LFCS measures have effectively controlled flooding. Today, most of major alluvial lowlands are no longer vulnerable to repeated flooding and the ratio of flood damage to the national income has fallen to less than 1%. Floods, however, still cause damage valued at 1–1.5 trillion yen per year.

2) Emerging new risks caused by intensive LFCS measures

However, intensive river improvement work based on LFCS has become the norm and one of the main factors behind such new risks as the increased potential for catastrophic flooding, more complex flooding in urban areas, deteriorating river environments, degraded soil and water cycles, and weakened disaster prevention efforts by local communities and residents.

To solve these problems, a new paradigm for flood control was implemented in the 1980s to (i) conserve and create rich natural river environments, scenery, and eco-systems; (ii) promote not only LFCS measures but also various measures in catchments to reduce flooding and damage; (iii) reduce flood risks with the participation of residents; and (iv) support lifestyles associated with rivers (MLIT, 2004).

3) Integrated approach to reducing LPHC-associated flood risks

The basic approach to mitigating LPHC flood risks should be strengthening embankments to prevent failures. However, such work is expensive and time-consuming as the embankments are longer and continuous (MLIT, 2004). To permanently reduce LPHC flood risk, this conventional approach should be shifted in favor of a comprehensive and integrated approach.

Before LFCS were introduced in the latter half of the 19th century, the intensity of floods was reduced through a combination of both physical and social measures. For instance, the force of the floodwaters was reduced by flood forests, while areas prone to flooding implemented retarding basins and second levee systems that redirected flood water to vulnerable low-lying areas.

Table 1. Measures to mitigate in flood risk in occurring process by local resident, local community, and government.

Flood disasters in occurrence process	Purpose	Government	Local Community	Residents
Rainfall ↓	**Reduce precipitation**	Activities to prevent: the rise in sea level enlargement of typhoon heat island	Activities to prevent worsening global environment	Activities to prevent worsening global environment Improvement in a lifestyle
(Catchments) ↓ Runoff ↓	**Reduce runoff generation & runoff concentration**	Disaster-resilient regional development without destructing water environment	Storing rainwater	Knowing the land condition & flood characteristics Water retention on the site
	Reduce flood wave propagation	Dam Retarding basin	Storing rainwater	Storing rainwater on the site
(River channel) ↓ Inundation ↓	**Inundation**	Flood control works ·bank ·urban drainage system ·pumping station	Ring levee Flood prevention forest Flood fighting (patrol,piling sandbags) Double embankment Floating weir	Trees around the residence Tax burden
(Exposure) ↓ Damage ↓	**Decrease vulnerability of Exposure**	Disaster-resilient social system ·land use management ·taxation system ·flood disaster prevention planning ·hazard map ·disaster education	Disaster-resilient community ·flood-fighting groups ·agree on mutual aid ·network in emergency ·transmit legends and advice ·participate discussion about safe community	Preparedness for flood disaster ·move to safety place ·ensure flood-resilient way of life; banking,flood-resilient house, insurance, and place for household goods & valuables ·prepare materials in case of emergency
(Social systems, etc.) ↓	**Reduce damage**	Providing disaster information Evacuation warning system Assisting volunteer group for disaster preventive activities	Flood fighting activities ·rescue mutual aid ·stop spreading damages ·gather and share information	Reaction to the emergency: ·pay attention to disaster information ·prepare for inundation and rain conditions ·evacuate
Damage	**Reduce damage**	Emergency management Restoration work Financial/Material aid Victim aid system Flood insurance Social/Economic recovery policy	Mutual aid First aid/Recovery Rescue Financial/Material Aid Volunteer/NPO/NGO	Reaction to just behind the disaster

Damage:human damage, economic loss, handicap for live, psychological damage, aggravation of natural environment
measures:deter & reduce damages, hard/soft, long/short-term, permanent/emergency, preventive/reform measures

Overflows were minimized through the use of sandbags filled and placed by the flood brigades of local communities. Small water retention facilities in the house yards delayed the runoff and reduced the peak flood discharge. These were some of the measures available to local communities and residents.

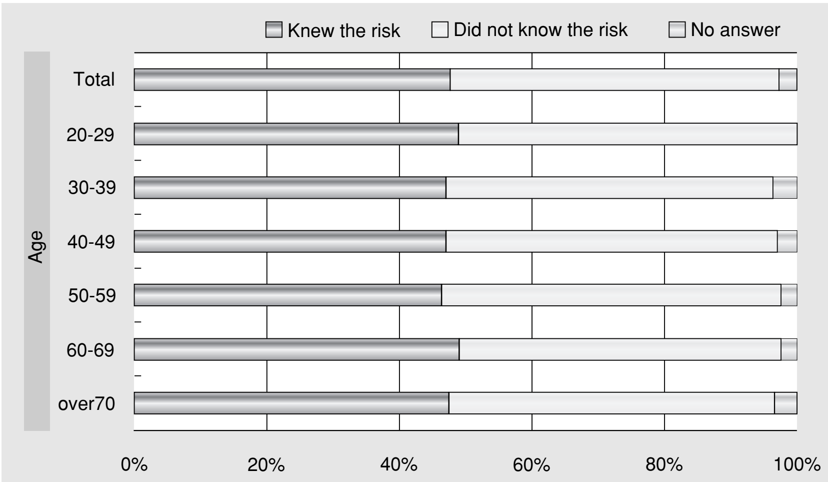

Fig. 6. Flood Risk Perception in the 2000 Tokai flood stricken area (T. Sato *et al.*, 2001).

3.3.2 Exposure management

1) Reducing vulnerability to flood risk

As mentioned above, the quality and quantity of damage caused by flooding has changed as a result of urbanization and more intensive land use. The potential for damage has increased along with the possibility of catastrophic damage from unexpected scale of flooding. New types of flood damage have also emerged. Few existing measures can reduce the vulnerability of the floodplains, and these measures are not effectively regulated in flood-prone areas. This is why urban areas potentially can suffer catastrophic flood damage.

It is the time to think seriously about managing decreasing the risk of flooding associated with urban planning. It is possible to decrease the potential for damage in flood-prone areas by managing land use through construction regulation, etc. Formerly, land use management reduced the potential for damage by placing houses on natural levees, in higher locations on floodplains, raising the foundations of homes, etc.

2) Worst-case risk scenarios

One of the lessons of the 2004 Niigata flood disaster is that the regional disaster plans and flood prevention plans developed by local governments must take into consideration the possibility of the embankments failing in a major flood. However, those responsibility for flood-disaster management in Niigata never considered such a possibility of embankment failure, so the measures taken were not always adequate. Moreover, many residents were not aware of the risk of LPHC type flooding and most had not implemented appropriate measures (Sato, 2006). Few local governments had emergency plans to deal with catastrophic flooding. Worst-case risk scenarios need to be explicitly incorporated into their disaster prevention plans.

3) Raising the residents' awareness to the vulnerability of their habitats

Fig. 6 shows the perceptions of residents regarding flooding prior to the severe 2000 Tokai Flood disaster. This survey was taken in the area stricken by the 2000 flood. Only 48–50% of residents of all ages knew of the vulnerability of their area to flood disasters (Sato, 2003). Residents need to raise their awareness of disaster prevention measures in order to decrease the vulnerability of their homes.

3.3.3 Damage management

1) Accepting flood risk

Reducing flood damage requires strengthening resilience of low-lying alluvial lands to unexpected scale of flood hazards. People need to understand that low-lying land cannot attaint "zero flood risk", and that they are to be ready for taking an acceptable level of flood risk. It is a myth that people always demand "zero flood risk". A survey taken in a flood prone area showed that 30% of the respondents accept the risk of flooding below the level of the tatami mats (straw floor mats) in their homes in every one to thirty years.

At one time, a culture for coping with local flooding was nurtured in local communities. For example, "Mizuya", which are annexed buildings specifically designed for use in flood emergencies, were built on higher ground and stocked with preserved food and a boat for use in an emergency evacuation center for the community. In those days, people also had the wisdom to mitigate their damage by themselves. For example, they used tatami (straw) mats to raise important belongings above the water level, and sealed the gaps between sliding doors with newspaper to keep out the water.

2) Reducing economic losses

Until recently, damage management placed priority on reducing the loss of lives by promoting the evacuation of residents. There was less interest in reducing economic loss of social infrastructures, and cultural and environmental assets. However, recent flood disasters have revealed the potential for damage from LPHC events in urban areas. It is now time to prepare for catastrophic economic losses caused by LPHC events by managing not only hazards but also exposure.

One interesting aspect of flooding is that the intensity and frequency can be controlled spatially. The old feudal government sometimes varied embankment heights to protect economic and political centers. These old ideas give us new insights into modern problems. For example, broad indirect damage can mitigate catastrophic economic losses by minimizing the flood risk over the entire catchment. This could be done by artificially or politically controlling the hazards spatially. However, spatial management of flood hazards has long been excluded from consideration under a current political system of local autonomy. Such measures may be controversial in certain regions, but they are worth considering given the potential catastrophic hazard. In fact, reports by the Niigata and MLIT Committees have touched on this idea (Niigata, 2005; MLIT, 2005).

3.3.4 Promoting disaster prevention activities by local communities

Flood brigades organized by local communities play a major role when emergency or disaster prevention activities require large numbers of people. Such activities include sandbagging and recovery work. It should be noted that these local flood brigades play a particularly important role immediately following the initial stage of flooding and until support is received from other regions. For example, during the 2004 Niigata flood disaster, at the initial stages of flood-combat operations, brigade members accounted for 30% of all individuals acting on behalf of the regional disaster prevention organizations.

In the past, communities had a spirit of mutual assistance and preparation regarding flood risk. However, the rapid decrease in the number of floods in recent years has reduced public experience with flood emergencies. Moreover, when the danger from flooding is inevitable, governments ask residents to evacuate via public warning systems. This approach ensures an appropriate level of safety. The result, however, is a weakening of the disaster-prevention activities of local communities. Urbanization has also led to the deterioration of local community relationships and increased the number of new residents who are unfamiliar with flooding vulnerabilities. Local residents and communities have left their safety in the hands of the government. According to our survey, even in Niigata, one of the most active regions in Japan for community flood-prevention activities, 50% of the residents were not aware of the activities of the local flood brigade (Sato *et al.*, 2006). Disaster prevention activities by local communities should be promoted in a new social scheme that includes coordinating new forms of social networks, utilizing modern communications technologies, etc.

4 Concluding Remarks

The characteristics of flood risk in Japan's urban areas, including components and structure, have changed drastically, both quantitatively and qualitatively, resulting in LPHC-type flood risk. Those are:

Changes in the characteristics of components

1) Flood hazard: Extensive development of LFCS has resulted in notably fewer and less intense floods. LFCS have changed the characteristics of flood runoff and made possible catastrophic flooding as a result of embankment failures. Cascading flood hazards are notable in urban areas.

2) Exposure: Growing populations and accumulations of assets in flood prone areas and more extensive land-use have increased the potential for damage. More extensive land-use and changes in urban and social structures have increased exposure and vulnerability and created new forms of flood risk.

3) Damage: Increased exposure in urban areas has made catastrophic flood damage more likely and changed the nature of the damage. Highly developed LFCS have deteriorated the river environments, soil, and water circulation system and weakened the disaster prevention activities of local residents and communities.

4) Social resilience to flood risk: The powerful LFCS type hazard control measures implemented by governments have become mainstream flood control policy. Extensive implementation of these LFCS type measures has produced the side effects mentioned above. "Zero risk Myth" has spread among residents and they have left their safety in the hands of the government. This has been accelerated by the decline of local communities under urbanization. We should lay the groundwork for re-implementing flood preventive activities by local communities and residents. Increased concern about river environments has led to river improvements that conserve the natural environment.

5) New LPHC type flood risks: The interaction of the changes in flood risk components has increased LPHC type flood risk in urban areas. This is the most important issue to be solved. However, few measures are currently available to reduce this type of flood risk. Not only must the embankments be strengthened to prevent failure, the powerful but limited LFCS approach must be augmented with a comprehensive and integrated flood risk management system that takes into consideration the process and structure of flooding while promoting various measures to reduce flooding, vulnerability, and damage. Such a system should incorporate all stakeholders, including governments, local communities, and local residents.

Long experience with flood disasters has given Japan an advantage in understanding the positive and negative consequences of disaster risk. To achieve a sustainable reduction in LPHC flood risk and avoid undesired risk caused by flood risk reduction measures, we need integrating different kinds of alternatives. We should also respect the diversification of values among people, make an adequate choice of effective and efficient methods for allocating resources, and encourage disaster prevention activities by residents, local communities, and governmental authorities.

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