A better integrated management of disaster risks: Toward resilient society to emerging disaster risks in mega-cities, Eds., S. Ikeda, T. Fukuzono, and T. Sato, pp. 177–192.


# The Niigata Flood in 2004 as a Flood Risk of "Low Probability but High Consequence"

Teruko Sato, Teruki Fukuzono, and Saburo Ikeda

## 1 Introduction

On 13 July 2004, torrential rains fell over the Chuetsu region of the Niigata Prefecture that were remarkable for the total rainfall and amount of rainfall within a relatively short period of time that triggered hundreds of landslide events-collapsing hillsides, mudslides, and debris-and in the alluvial lowlands, the Ikarashi, the Kariyata, and other small to medium-sized rivers feeding into the Shinano River broke through their levees. Large-scale flooding devastated Sanjo City, Mitsuke City, and Nakanoshima Town where 16 people died, 2,500 hectares of land were inundated, 29 homes completely destroyed, 158 homes partly destroyed, 13,289 homes with major water damage, and 6,199 other buildings severely damaged. This disaster is referred to as the Niigata flood of 2004 or simple the flood.

The flood was primarily caused by the failure of the local levees, a highly unusual low probability but high consequences (LPHC) event because the levees are built to withstand torrential rain-induced flows. We begin by exploring the nature and exposure to flood hazard and by defining a damage and loss-risk structure framework. Then in the rest of the paper, we will describe the actual conditions and particulars of the Niigata flood risk.

## 2 Region and Drainage Environment of the Study

### 2.1 Topography

The Niigata Plain is an alluvial plain formed by centuries by flooding of the Shinano River. The plain is flat and narrow, sloping from north to south (see Fig. 1) with beach ridges and sand dunes to the west (i.e., on the Japan sea side) and hilly and higher mountains to the east. Starting at an elevation of about 19 m in the vicinity of Nagaoka City, the plain slopes gradually at a rate of about 0.7 to 0.8 m per 1,000 m and continues until the Nagaoka lowlands to the south and the Shinano River lowlands to the north (refer to the topography map). The Shinano River lowlands consists of formerly filled lagoons in which drainage is deficient and are frequently subject to flooding.

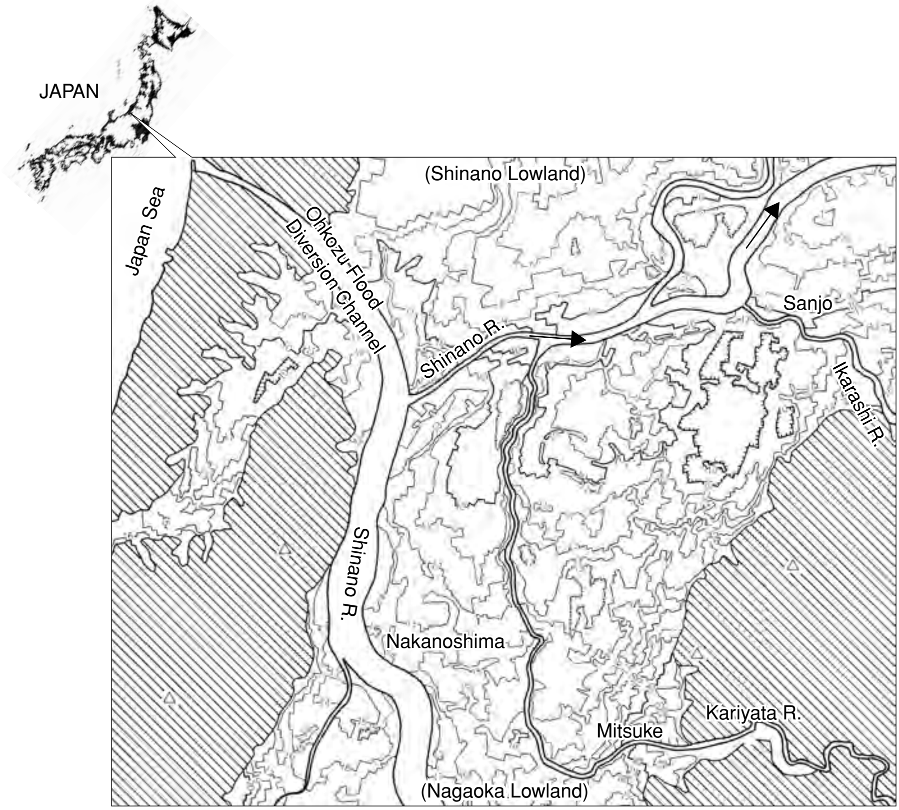


Fig. 1. Contour map of the alluvial plain of the lower reaches of the Ikarashi and Kariyata Rivers in the Chuetsu region.

The section of the Shinano River from the intake of the Okozu Flood Diversion Channel to the river mouth is called the lower reaches of the Shinano River. When the water level is low, the lower reaches of the Shinano River functions as the lowest downstream section of the Shinano River with a channel length of 367 km and a drainage area of 11,900 km$^2$. But when flooding occurs, all the flood waters flow from the Okozu Flood Diversion Channel to the Japan Sea (Fig. 1), and the lower section of the Shinano River becomes a major catchment basin that is independent of the upper reaches of the river. When this occurs, the drainage area shrinks to 1,420 km$^2$ and channel length to 58.2 km. In other words, under flooding conditions, the Kariyata and Ikarashi Rivers function as the uppermost tributaries feeding into the lower reaches of the Shinano, such that the upper section of the Shinano has little

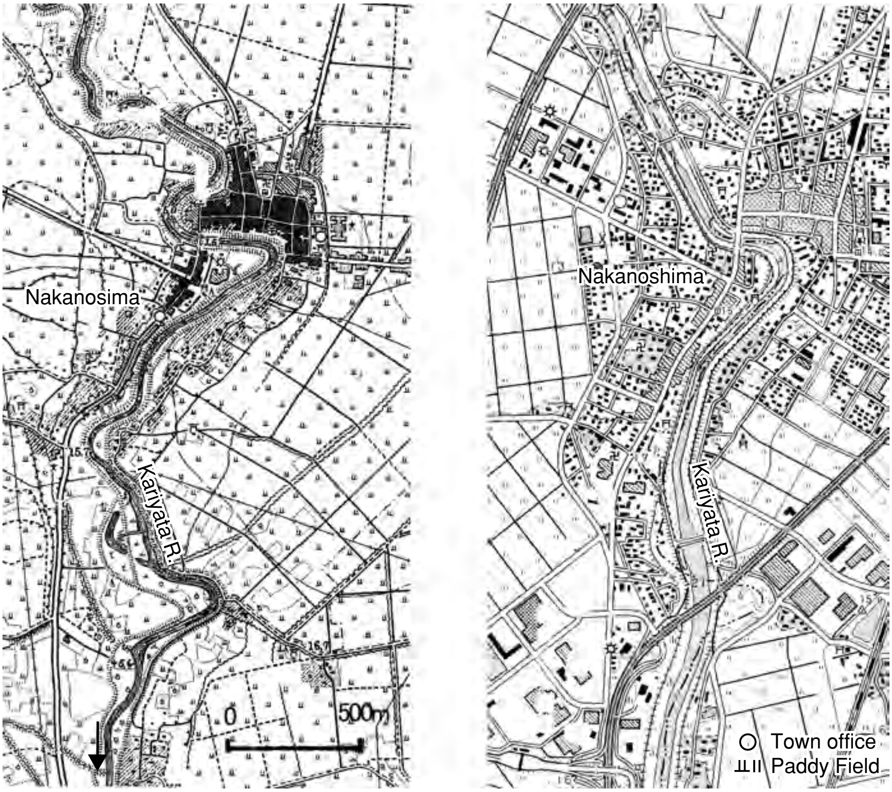


Fig. 2. Change of the land use of the Nakanoshima Town along the Kariyata River from 1948 to 2001.

effect on the flood runoff to the lower section of the river, while the two tributaries -the Ikarashi and the Kariyata- have an enormous impact on flooding in the lower drainage of the Shinano River. On the other hand, the slope of the lower reaches of the Shinano River and the two tributaries is gradual, so when the water level of the Shinano River rises, the backwater effect impedes the flow of the tributaries and the flood flow.

### 2.2 Flood history: social and land use changes and increased damage potential

Flood flows and the incidence of floods on the lower reaches of the Shinano River have markedly decreased since completion of the Okozu Flood Diversion Channel in 1931, but major flooding sometimes occurs on the Ikarashi and Kariyata tributaries. Levees failed due to flooding on both rivers in 1964, and levees along the Ikarashi River were breached in 1978. Thus, the alluvial lowlands of the lower reaches of both these rivers have seen floodins in the past and today, although flooding occurs less frequently, there is nevertheless a potential flood hazard in this area.

Figure 2 shows side-by-side topographical maps of Nakanoshima Town in 1948 and 2001. Comparing the two maps, one can see the extent that housing and factories and warehouses have encroached upon what were formerly wetlands used as rice paddies. It is also apparent that the Town office formerly built on a natural levee along the river at an elevation of 15.4 m has now been moved to reclaimed land on infilled wetland. The old commercial district of Sanjo City developed along the natural levee on the right bank of the Ikarashi River, but now the newer district of Rannan, has been built on the left bank and the commercial district pushed out into former paddy lands. In Mitsuke City too, there are ongoing efforts to upgrade and improve the river channel, the former now-abandoned river channel has been converted for commercial purposes, and paddy fields on the left bank of the river are also giving way to commercial development.

### 2.3 Awareness and responsiveness to flood risk: low probability but high consequences events

The 2004 flood was the first time in 40 years that the Chuetsu area has been by such massive flooding due to the failure of levees. Yet the potential for large-scale flooding is still clearly there. Given the region's potential for massive destruction from flooding, what is the degree of awareness of the local governments and inhabitants to their vulnerability to flooding?

Regarding flooding of the Ikarashi River, Sanjo City's "Community Disaster Prevention Plan 2003 Revised Version" states that "· · ·the Ikarashi River is not very safe. Although some flood control is provided by upstream dams, there are occasions when the levees leak or even fail as a result of heavy rains. Furthermore, when the water level of the Shinano River rises, this impedes drainage of the Ikarashi River into the Shinano River , which causes the level of the Ikarashi to rise and increases the danger of flooding." In addition, the "Sanjo City Flood Control Plan" notes that, although there are eight places along the Ikarashi River susceptible to flooding, critical flood controls are being implemented because levee failure is clearly a prospective danger. And yet in our interviews with local officials in Sanjo City, Mitsuke City, and Nakanoshima Town, we did not find one official who foresaw the failure of the levees. In addition, we noticed that all the recent disaster-prevention drills carried out by the City of Sanjo assumed an earthquake as the disaster, and no drills based on the assumption of a flood had been carried out for quite a long time.

The local inhabitants also felt secure in believing that the Ikarashi River would not flood, but, based on a fact-finding survey of people living in the stricken area gauging people's response to proposed river infrastructure improvements decided after the flood, their confidence had been expressed more symbolically. According to the Sanjo City Director of Public Works, "In 1996 when the previous Mayor was in office, the city in cooperation with the prefecture handed out a pamphlet detailing an Ikarashi River infrastructure improvement plan to every household in the district and warned people that the river was narrow and definitely posed a danger, but the response was pretty lukewarm. The fact that dams had been built upriver and no flooding had occurred for 40 years pulled most people into a false sense of security."

The National Research Institute for Earth Science and Disaster Prevention (NIED) conducted a questionnaire survey after the flood (Research Project on Societal Systems Resilient Against Natural Disasters, 2005), and asked people in the community "Do you know of anything that the volunteer Flood Brigade did to alleviate the disaster?" About 30% of the respondents said that they "did not know anything that the Flood Brigade did to help the situation," a percentage that increases to 50% if you include the respondents who "couldn't say one way or another whether the Flood Brigade helped". We also got a mixed response when we asked people if the "actions of the Flood Brigade were effective in mitigating hardship from the flood?" About half the respondents felt that the Flood Brigade was "somewhat effective" or "very effective" (42.2%), but an even larger percentage of people felt that the Brigade's actions were "not especially effective" or "can't say if their actions were effective or not".

Based on these responses, it is apparent the people's awareness about the risk of flooding and their concern about the activities of the Flood Brigade are fairly low.

## 3 Response to Flood Risk

### 3.1 Flood Mitigation Response by the Government

#### 3.1.1 Tangible flood control initiatives

Table 1 shows the milestones of flood control infrastructure improvements on the Ikarashi River. Levee building on the Ikarashi was spurred by a major flood in August 1872, and construction of the levee on the left bank of the river was completed in 1877. A major river infrastructure improvement project was begun in November 1933 after another disaster in 1926 and by 1937, the river control infrastructure that you see on the Ikarashi today was more or less in place. Major floods were averted after that, but torrential rain and flooding in August 1961 resulted in the Mikura and Watarase bridges being washed out,

Table 1. Changes of the design flood discharge of a river channel.

| Year | Design Flood Discharge ($m^3$/sec) | Design Flood Discharge of a river channel ($m^3$/sec) | Contents of Improvement works | Triger of the work |
|---|---|---|---|---|
| 1875 | - | - | Construction of levee on the left side of the river in lower reaches (completion in 1977) | Aug. 1872 Flood |
| 1933 | - | 1,120 | River improvement works, Construction of levee, and bank protection work (completion in 1926) | July 1926 Flood |
| 1961 | 2,000 | 1,600 | Construction of Kasahori dam (completion in 1964) | Aug. 1961 Flood |
| 1980 | 3,600 | 2,400 | Construction of Ohtani dam (completion in 1993) | Aug. 1969 Flood |

an incident that led to the construction of the Kasahori dam in 1964, which permitted the design scale of the river to be revised up to 1,600 $m^3$/sec. Then after disastrous flooding in August 1969, the Otani Dam was completed in 1993, which allowed revision of the river's design scale to 2,400 $m^3$/sec, and the basic high-water flow capacity to 3,600 $m^3$/sec (Niigata Prefecture data, 2005).

Work began on the Kariyata River after a flood in 1949, and even more substantial public work was done on the Kariyata River after a disastrous flood in 1964, at which time the Kariyata dam was planned. The design scale of the river was revised upward several times to 950 $m^3$/sec, 1,050 $m^3$/sec, and finally to 1,550 $m^3$/sec with a basic high-water flow capacity of 1,700 $m^3$/sec when the dam was constructed. Through these repeated public works improvements, the incidence of flooding on the Ikarashi and Kariyata Rivers was greatly reduced, communities were spared common flooding, and the risk of rains heavy enough to cause flooding was reduced to about once every 100 years. But the possibility of large-scale flooding that exceeded the design scale of the local rivers was never entirely eliminated. Indeed, as we shall describe, a scenario emerged of a new potential risk of substantially larger-scale hazards as a result of levee failure.

### 3.1.2 Intangible damage mitigation initiatives

It is apparent though interviews with local officials that the main thrust of preliminary disaster preparedness in the stricken area was to rely on large-scale public infrastructural improvements -continuous high levees and dams- for flood hazard control, and not enough concern was given to intangible flood mitigation efforts. Earlier we described how there was little awareness among local officials and the local populace about the risk of flooding, and it is apparent from our interviews and from newspaper accounts, that genuine advance preparedness for flooding by the government and the local people was inadequate. For example, in Nakanoshima Town "it was known that the waters of the Kariyata River had reached dangerously high levels two hours before the levees failed, but they stepped up inspections and, based on past experience, issued an evacuation advisory just before the levees actually failed, saying that the situation was under control". The fact that the town offices were inundated is another indication that advance flood preparation was insufficient.

### 3.2 Local and citizens' response: Efforts by the local fire brigade and volunteers

Although the local populous was only dimly aware of the flooding risk, the Volunteer Flood Brigade (organized on a community basis) played a major role in mitigating hardship and damage from the flood. Beginning in the early morning of 13 July 2004, there was one catastrophe after another in Sanjo City: slope failures, inland flooding, rising water level in rivers, and the waters of the Ikarashi started coming over the levee. In the midst of efforts to respond to all these crises by the city, the Fire Department, the Volunteer Flood Brigade, and others, at 1:15 in the afternoon the Ikarashi River levee failed. First water started coming over the top of the levee at 12:40, then 10 minutes later the back of the levee began to be eroded. By 1:00 a 50-m breach had opened up and a muddy torrent of water was pouring through, and at 1:25 the levee failed and a huge breach 117 m across was washed out.

By nightfall, the entire Rannan District was covered with water up to 2 m deep in some places. Rescue efforts began immediately after the levee failed with a total man-days of 4,500 people involved in the effort, including volunteer Flood Brigade personnel from nearby cities and towns, members of the Self Defense Forces, coast guard personnel, policemen, and others. Close to 40% or 1,800 of these rescue workers were members of the Volunteer Flood Brigades, from Sanjo City itself and other nearby cities and towns (see Fig. 3-1).

By the morning of 15 July the waters had receded, and by nightfall the emergency call-out of regular and volunteer flood fighters was cancelled. Then the cleanup efforts started when 29,000 volunteers descended on the disaster-stricken area to help the victims clear mud and debris from their homes.

At the initial stage of seeing multiple crises unfolding across the entire city at the same time, the government realized that it was going to take substantial human resources to cope with the situation. Considering that the Ikarashi levee had already sprung leaks, overtopped, and failed in 13 places, it was

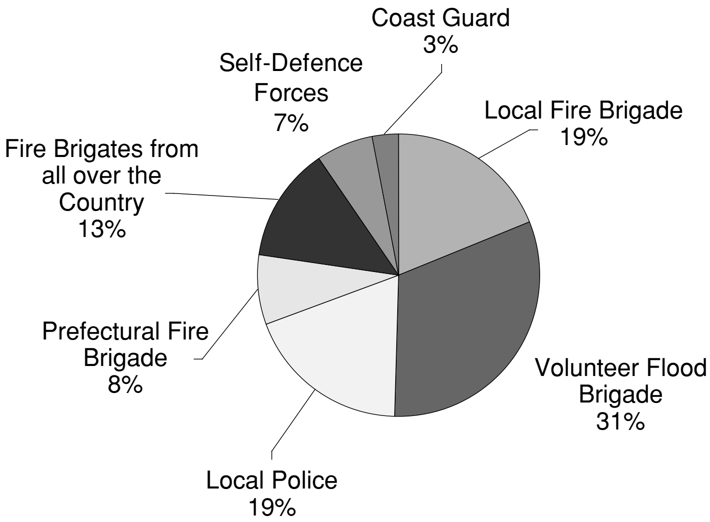


Fig. 3-1. Flood fighting and rescue operations by disaster prevention related agencies in the Sanjyo City.

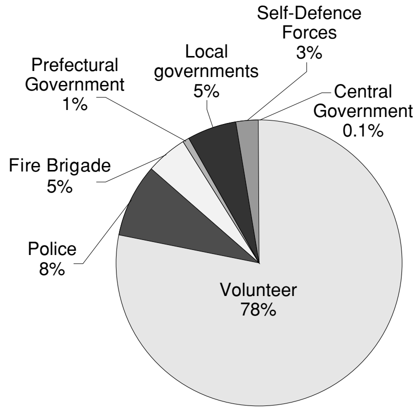


Fig. 3-2. Recovery operations by disaster prevention related agencies in the Sanjyo City.

entirely possible that the levee could fail elsewhere, so in addition to the regular firefighters employed by the local government who numbered only 152, the government also mobilized 1,166 workers from the volunteer Flood Brigades (7.7 times the number of regular firefighters). Massive human resources were committed to the flood control efforts that were needed at many different places at the same time, and the additional manpower provided by the

Photo 1. Flood-fighting activities to prevent water leakage of the levee.

Volunteer Flood Brigades made up of local communities was indispensable. Photograph 1 shows the flood control activities in progress.

After the disaster had occurred, Flood Brigade volunteers from throughout the prefecture and beyond were quickly mobilized through extensive government coordination, and rushed to the scene to help fight the flood and assist the victims. The involvement of the National Disaster Volunteer Center that organized 30,000 volunteers to come in and help with the cleanup and restoration in the aftermath of the flood, also deserves special mention (Fig. 3-2).

## 4 Extent of Devastation

During the Niigata flood of 2004, levees failed at 11 different places on six different small-to-medium-sized rivers throughout the Chuetsu region in the Niigata prefecture, and more than 340 mudslides were counted throughout the prefecture centering again on the Chuetsu region. In the Ikarashi River drainage area, this resulted in the inundation of 490 ha of residential neighborhoods and 830 ha of farmland, and in the Kariyata River basin, 250 ha of residential land and 903 ha of farmland were flooded, for a total of 2,473 ha of farm and developed land covered by the flood waters. In Sanjo and Mitsuke Cities 2,914 non-residential buildings were damaged or destroyed, a number far in excess of the 1,776 building destroyed in the previously most destructive flood. Sanjo suffered the greatest number of casualties with nine deaths caused by the flood, and 12 of the victims were elderly people in their 70s.

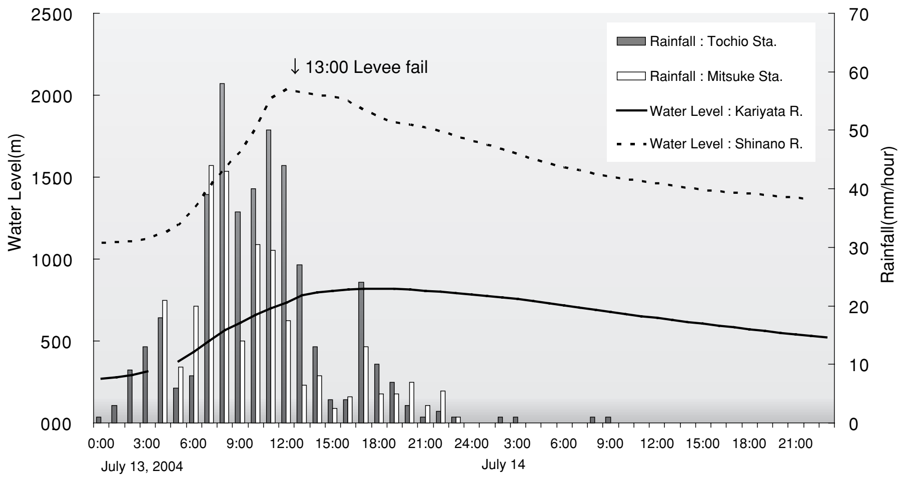


Fig. 4-1. Hydrographs of the Kariyata and Shinano Rivers and hourly amount of rainfall.

The total financial losses resulting from the disaster were ¥200.125 billion (Niigata Prefecture Public Works Department River Management Section, 2005), of which 98% was attributed to flooding (¥196.1225 billion) and 2% attributed to mudslides (¥4.0025 billion). Breaking down the economic losses by sector, 71.62% (¥100.545 billion) of the damage was to the private sector property, 0.44% (¥900 million) to public utilities, and 27.94% (¥57 billion) to public works infrastructure.

Turning now to loss density, we find that dividing Sanjo's private sector economic losses of ¥82.3 billion by the total number of residential hectares in Sanjo, that were inundated (490 ha), we obtain a loss density (i.e., private losses per ha) of ¥170 million per ha. Nationwide, we have been observing a trend toward increasing loss density in recent years. The devastation of commercial parts of Nagoya by the Tokai flood in 2000 when the Shin River levee failed, resulted in a loss density of ¥121.583 million per ha (Sato, 2002). The fact that the loss density of the Sanjo City flood tops even that figure, reveal just how destructive the Sanjo flood was.

Along with the structural damage, much of what people had inside their homes-tatami mats on the floor, furnishings, and so on-was ruined and added to the vast amount of flood-damaged refuse that was discarded. These mountains of water-damaged garbage hampered cleanup efforts in the flooded neighborhoods, and concerns over sanitation and environmental contamination also slowed down the restoration work and had other detrimental effects.

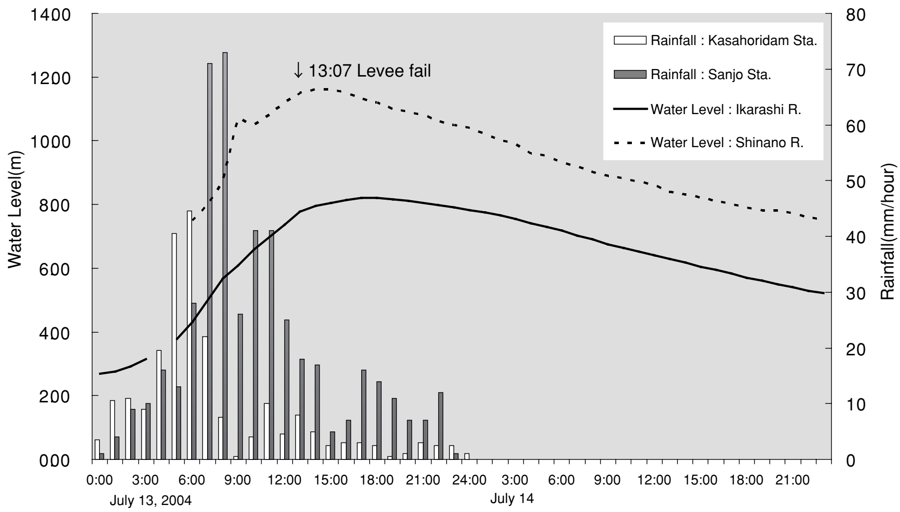


Fig. 4-2. Hydrographs of the Ikarashi and Shinano Rivers and hourly amount of rainfall.

A month after the flood, the local newspaper reported that, on 12 August close to 48,000 tons of garbage resulting from the flood had been collected at three makeshift sites including the former Sanjo horse track, and it was going to cost more than an estimated ¥2.6 billion to dispose of the garbage (*Niigata Nippo*, 17 August, 2004).

## 5 Characteristics of the 2004 Niigata Flood Hazard

### 5.1 Rain

The cause of the 2004 Niigata floods was the inordinate amount of rainfall—both the total amount and rainfall over a short period of time—that was intensified by the seasonal rain (baiu) front that stalled over the region. The rain extended over the entire lower reaches of the Shinano River, and was especially intense over the drainages of the Ikarashi and Kariyata Rivers in the Chuetsu region. The headwaters of both rivers received 200–400 mm of precipitation over a 24-hour period (see hourly rainfall for the Kariyata River drainage in Fig. 4.1).

Reconstructing torrential rain patterns over different intervals based on precipitation data collected over a 23-year period (1979–2002) by the AMeDAS (Automated Meteorological Data Acquisition System) rain observation station at Tochio, Niigata, it was found that 422 mm of rainfall over a 24-hour period would occur every 530 years, 267 mm of rainfall over a 6-hour period would occur every 500 years, and 58 mm of rainfall in a 1-hour period would occur every 208 years (JSCE, 2004). Figures 4-1 and 4-2 show hydrographs for Mitsuke on the Kariyata River and Sanjo on the Ikarashi River, respectively. In the Kariyata watershed, the most intense rainfall of 58 mm/hour fell upriver on Tochio between 8 and 9 in the morning, but peak flooding did not reach Mitsuke at the foot of mountains until 1 to 2 in the afternoon, so there was a lag of about 4 hours between the heavy rainfall over the headwaters and the peak flooding that can be partly attributed to the water storage capacity of the upstream dam. In the Ikarashi River, the peak flooding reached the alluvial lower reaches after an 8-hour delay. If the flood arrival time is two times the time difference between the rainfall and when the peak flood flow appears, this yields a value of 8 to 16 hours. Thus the amounts of rain when the Niigata flood occurred were equivalent to a precipitation event that might occur once in approximately 500 years, and this concentrated torrential rain caused the water levels recorded at many of the observation stations along the rivers to break all previous records.

### 5.2 Conditions exacerbating the flood hazard

Typically, flood waters in the lowlands downriver from the Ikarashi and Kariyata Rivers flow slowly because the slope is fairly gradual, but the scale and character of the 2004 Niigata flood were vastly different because the removal of structural impediments when the levees failed resulted in a powerful flood flow that swept through the breach to cover an immense area.

### 5.3 Increased volume of inland flooding due to levee failure

Approximately 13.93 million $m^3$ of water poured through the breach in the left bank levee of the Ikarashi as opposed to only 340 thousand $m^3$ of water that came over the top of the levee in that sector. It is thus clear that the overwhelming bulk of flood waters that inundated the inland area (about 98% of the total) can be attributed to the failure of the levee. In other words, the failure of the levee resulted in a sudden surge of massive amounts of flood water, so that a much more extensive area was inundated with deeper water, and the force of the flood water surge was extremely powerful around the breach.

Photograph 2 shows the breach in the Kariyata River levee in Nakanoshima at 6:11 pm. The Buddhist temple Myoeiji that stood close to the breach has already been swept away, and houses in the area are submerged up to second floor level. Levees are intended protect the inland areas and communities behind them, but when they fail they expose these same communities to massive devastation from surging flood waters.

Photo 2. Flood water flowing into the housing area from the bank break site of Kariyata River (Photo by Kyodo-Tushinsha).

### 5.3.1 Increased flood flow hydrodynamic force due to levee failure

The flood plain around where the levee failed slopes very gradually at a rate of about 0.7 to 0.8 meters per 1,000 m, so the flood waters that came over the top of the levee flowed very placidly. But the flood waters that surged through the breach in the levee were extremely powerful, indeed so powerful that many homes located even considerable distance from the breach were completely destroyed within a very short time. Members of the 7.13 (13 July) Niigata Rain and Flood Disaster Survey Committee charged with investigating the flood have discussed at length whether this incredible surge force of the water through the breach can be attributed to the difference in water level between the river channel and the lowlands behind the levee, or to the abruptness with which the levee failed (Niigata Prefecture).

### 5.3.2 Increased flood peak flow and infrastructure improvements

Earlier we have described how flooding on the Ikarashi and Kariyata Rivers and the history of efforts to cope with the flooding exhibit a classic pattern of flooding⟶flood control improvements⟶more flooding⟶more flood control improvements⟶levees fail⟶massive flooding. Certainly, these repeated public works infrastructure improvements have enhanced flood control safety, reduced the incidence of flooding on the Ikarashi and Kariyata Rivers, and spared downriver communities from common flooding. Yet we must also realize that straightening out meandering river channels and building long continuous levees to inhibit flooding upriver can have the adverse effect of enabling substantially greater flood flows on the lower reaches of the river. We would also note that infrastructure improvements increase the volume of flood flow waters that course through river channels by 2.1 to 2.4 times, and considering that the difference in elevation between the water level of flooded rivers and the inland areas behind the levees in downriver areas is close to 5 m, people must be prepared for much larger-scale flooding in the event that levees do fail.

## 6 Summary

A major flood disaster occurred in Niigata Prefecture on 13 July 2004 as a result of heavy rainfall that exceeded the design scale of the river infrastructure. Flood waters breached the levees in downstream urban areas, causing tremendous damage. Examining the flood from the perspectives of risk theory, we observe the following specific characteristics:

1. The flood was of a low probability but high consequences (LPHC) type; that is, an event that rarely occurs, but results in catastrophic damages when it does occur.
2. Factors contributing to increased flood hazard were (1) levee failure due to flood waters far exceeding the design scales of the rivers, which increased the force and volume of the flood waters, and (2) development of a narrow valley plain without considering the potential for LPHC-type flooding.
3. Private sector economic losses were substantial at ¥154 billion, representing 71.62% of the total economic losses. This is the second highest percentage of private sector losses in Japan's history, only exceeded by a loss figure of 80% in the Tokai flood that devastated urban areas of Nagoya in 2000.
4. In terms of human suffering, a large number of the casualties were elderly. This could be seen as a reflection of the aging of Japanese society.
5. Regional disaster prevention plans and flood prevention plans created by local governments consider the possibility that levees might fail in the event of a major flood. However, local officials in charge of flood-disaster management had no true sense that such an event might ac-

tually occur, so advance measures and preparations were insufficient. Local residents also showed little awareness of the danger of LPHC type flooding, and almost none had made any advanced preparations.

6. Locally organized Flood Brigades played a major role in efforts involving large numbers of people mobilized to undertake rescue and recovery activities. Indeed, these local Flood Brigades were on the scene almost immediately after the flood occurred, and until support started to arrive from other regions, they accounted for 30% of the total number of people on the ground working on behalf of the regional disaster prevention organizations.

We should also note that, according to some reports, Flood Brigade efforts to stem overtopping by piling sandbags on the levees was a key factor in the eventual failure of the levees, which of course was the primary cause of the devastating inland flooding.

## Materials and Data

**I Local Government Materials**

1) Niigata Prefecture, materials relating to the July 2004 Niigata flood disaster.

2) Mitsuke City, materials relating to the July 2004 Niigata flood disaster.

3) Nakanoshima Town, materials relating to the July 2004 Niigata flood disaster.

4) Sanjo City, materials relating to the July 2004 Niigata flood disaster.

**II Government Institute Materials**

1) Ministry of Land Infrastructure and Transport River Bureau, materials relating to the July 2004 Niigata flood disaster, http://www.mlit.go.jp/.

2) Ministry of Land Infrastructure and Transport Hokuriku Regional Development Bureau, materials relating to the July 2004 Niigata flood disaster, http://www.hrr.nilit.go.jp/.

3) Cabinet Office, Government of Japan, materials relating to the July 2004 Niigata flood disaster.

4) Fire and Disaster Management Agency, materials relating to the July 2004 Niigata flood disaster.

5) Niigata District Weather Station, weather information relating to the July 2004 Niigata and Fukushima flooding (final report), p. 25.

**III Newspaper Articles**

1) Articles in *Niigata Nippo News*, July 14 to September 30, 2004.

**IV Maps**

1) Geographical Survey Institute maps.

1:25,000 scale, Mitsuke City, source revised and published in 1948, updated and revised in 2001.

Sanjo City, revised in 1931, source revised and published in 1948, updated and revised in 2001.

1:200,000 scale, Niigata and Nagaoka 1996.

1:25,000 scale, topographical map, p. 11.

2) Geographical Survey Institute, 1:25,000 scale, Sanjo, topographical map, p. 11, 1990.

3) Nakanoshima district planning map.

4) Mitsuke City planning map.

5) Sanjo City planning map.

## References

Japan Society of Civil Engineers (JSCE) (2004): "July 2004 Hokuriku Heavy Rain Disaster Emergency Investigation Commission materials", August 31 (in Japanese).

Hokuriku Construction Association (2004): Hotto Hokuriku, July 2004 Special Issue, No. 43 (in Japanese).

T. Sato (2005): "Flood Risk Structure and Characteristics: Toward an Integrated Flood Risk Management Framework", *Keio University Hiyoshi Review of Social Sciences*, 15, pp. 25–38 (in Japanese).

T. Sato and K. Nakane (2004): "Course of Events of Sanjo City Flood Disaster", *Chiri*, Vol. 49, No. 12, Kokon Shoin, pp. 28–31 (in Japanese).

T. Sato, K. Seo, S. Ikeda, and T. Nagasaka (2005): "Cooperation Between Local Governments and Disaster Prevention Organizations in the 2004 Chuetsu Earthquake", Chuetsu Earthquake Disaster Survey Report, a urgent research project supported by special coordination funds for promoting science and technology (in Japanese).

T. Sato (2002): "Time and Spacial Distrubution of the Damage in the 2000 Tokai Urban Flood Diasters", Natural Disaster Research Report, No. 38, National Research Institute for Earth Science and Disaster Prevention (NIED), pp. 99–161 (in Japanese).

T. Sato, K. Nakane, S. Ikeda, and T. Nagasaka (2006): "Characteristics of the Flood Risk of the 2004-Niigata Flood Disasters", Natural Disaster Research Report, No. 40, National Research Institute for Earth Science and Disaster Prevention (NIED), pp. 33–78 (in Japanese).