AN URBAN FLOOD IN THE KASHIO RIVER BASIN

Iware MATSUDA

Abstract An urban flood is one of knotty problems derived from land development. Taking the Kashio River basin of Kanagawa Prefecture as an example, the relationships between urbanization and flood hazards were historically discussed. It was explained that a flood prevention work in one area affects other areas. The historical change in conditions for flood hazards can be divided into six stages.

1. Introduction

Floods commonly occur through excessive rainfall. However, extent of flood damage is influenced, not only by amount of precipitation, but also by accumulation of property in a lowland, including actual flood prevention works. As urban land use expands within a river basin, it becomes more difficult for rain water to permeate the soil and rapid drainage into a river through improved drainage facilities is likely to follow, increasing the risk of flood.

Land development has to keep pace with safeguards against natural hazards, but in many cases these are only implemented once a disaster has occurred, while effective counter-controls would have lessened the probability of a flood. Low probability of flooding invites development and the accumulation of people and properties in the lowland, and flood damage potential (it is shown by the product of the probability of occurrence of a flood and the expected amount of damages caused by inundation) increased accordingly. Development of a river basin affects the rainfall-runoff system through extension of impermeable areas and construction of stormwater drains. In these circumstances, a flood disaster is prone to occur, necessitating a new set of countermeasures. Changes in natural conditions in a river basin where urbanization is proceeding follow this cycle of development-flood hazards-countermeasures, and the character of flood hazards will also gradually change as the river basin becomes more unnatural. These changes are irreversible.

In this descriptive report, the author will take the Kashio River basin as an example and will discuss the history of the artificial changes which have taken place and also an instance of an urban flood.

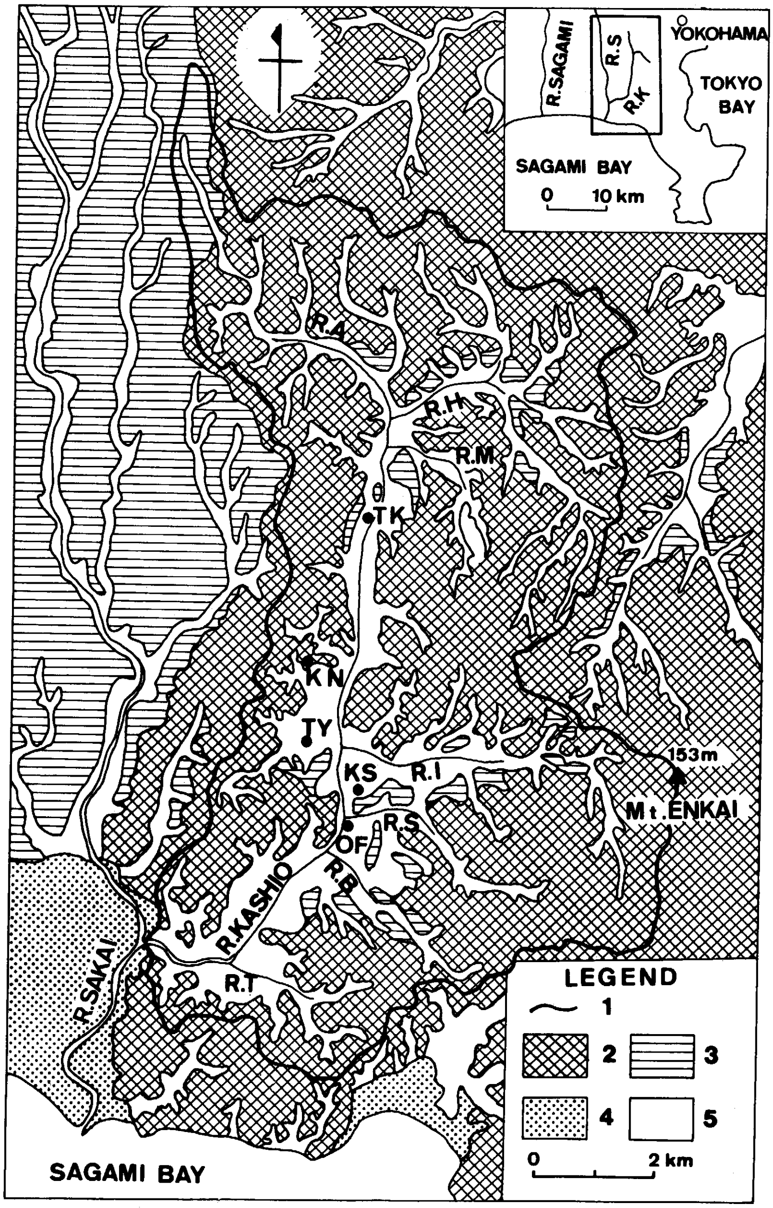

Fig. 1 Landform classification in and around the Kashio River basin
Landforms: 1: Boundary of the Kashio River basin, 2: Hill, 3: Terrace, 4: Sand bar, 5: Alluvial lowland;
Name of rivers: R.K: Kashio River, R.S: Sakai River, R.A: Akuwa River, R.B: Kobukurotani River, R.H: Hiratonagaya River, R.I: Itachi River, R.M: Maioka River, R.S: Sunaoshi River;
Place Names: KN: Kanai, KS: Kasama, OF: Ofuna, TK: Totsuka, TY: Taya.

2. Urban Development and Flood Hazards in the Kashio River Basin

An outline of the Kashio River basin

The Kashio River which is one of the tributaries of the Sakai River runs from north to south in the western part of Yokohama City and meets the main stream at Kawana in Fujisawa City. The length of the Kashio River is about 16.6 km and the area of its basin is approximately 8,378 ha. Yokohama City occupies 73.3 % of the river basin, 24.1 % belongs to Kamakura City and 2.6 % to Fujisawa City.

Almost all areas of the river basin are lower than 100 m in height. Landforms of here are classified into low relief hills, terraces and alluvial lowlands (Fig. 1). The low relief hills and terraces occupy 70.8 % and 7.2 % of the river basin, respectively. The terraces distribute along the tributaries. Among them, the terrace along the Akuwa River is a part of the Sagamino Terrace distributed along the Sakai River. The alluvial lowlands composed of narrow valley flats and flood plains occupy the remaining 22.0 %. Dendritical valley flats are distributed along the upper course of the tributaries.

The flood plain developing along the main stream of the Kashio River between the confluence of the Akuwa and Hiratonagaya Rivers and the junction with the Sakai River is named as the Kashio Lowland in this paper. The Kashio Lowland is about 400 m wide and about 4 m high near the junction of the Akuwa and Hiratonagaya Rivers. The Kashio Lowland broadens to about 800 m near Totsuka, and between Taya and Kasama, at a height of 9 m, narrows to a width of only 200 m. Thus the gradient of the Kashio Lowland between the confluence of the Akuwa and Hiratonagaya Rivers and a point near Taya is about 1 to 1,000.

The Kashio Lowland widens to more than 1 km again along the lower course of the river. As the height of the Kashio Lowland is about 4 m near the confluence of the Sakai and Kashio Rivers, the gradient in the lowest course of the river is only 0.5 to 1,000.

The present Kashio Lowland was formed in a deep valley which was dissected during the Würm Ice Age and drowned by Frandrian transgression, forming narrow estuary. The latter was subsequently filled by sediments brought down by the Kashio River and submerged for several thousands of years. The very flat and low relief of the Kashio Lowland derives from a geohistory of land development common to most flood plains near coastal areas in Japan.

Table 1 Population in the Kashio River basin on October 1, 1986

Name of city	Whole Basin		Lowlands prone to flooding	
	Number of households	Population	Number of households	Population
Yokohama	126,700	401,300	23,200	68,700 (17.1%)
Kamakura	34,000	98,600	11,600	30,500 (30.9%)
Fujisawa	3,500	10,000	2,100	6,000 (60.0%)
Total	164,200	509,900	36,900	105,200 (20.6%)

Main land use was forest in the hills, while terraces and alluvial lowlands were used, respectively, for vegetables or mulberry and paddy fields. Urban land use, has become dominant since the 1960s. The river basin has a total population of 509,900 and about 20.6 % of this number live in alluvial lowlands that are prone to flooding (Table 1).

Land use development and the Kashio River

In the middle of the 19th century (at the end of the Edo era), the Kashio River was about 9 to 18 m wide and meandered through paddy fields of the Kashio Lowland. Continuous banks were constructed only near Totsuka on the right riparian zone and between Totsuka and Kanai on the left (Nozawa, 1981). We can determine land use in this area for 1882 on the basis of the *Jinsoku-zu* which is the first formal topographic map published in Japan on a scale of 1 to 20,000. Paddy fields were developed broadly and buildings were constructed only along the Tokaido Road.

The national government in 1899 established the law concerning a readjustment work for arable land aimed at more productive use of agricultural land. On the basis of this law, a readjustment work between Kasama and near Totsuka in the Kashio Lowland was carried out from 1907 to 1910 and represented the first large-scale human works undertaking in the Kashio River basin. Water-use facilities were constructed along the river, the meandering course was straightened and continuous banks were built along both riparian zones. A prototype of the present Kashio River was established by these earthworks. The latter protected paddy fields from floods and rice production increased. However, the Kashio River was liable to overflow its banks in its lower course, because flood water was carried directly downstream with no chance to lie in the upper course area. Many disputes about flood control in the lower course area occurred following the land readjustment project.

The Tokaido Line was opened to traffic between Tokyo and Kobe in 1889 and two railway stations, Totsuka and Ofuna, were located in the Kashio Lowland. Also, the south-bound Yokosuka Line from Ofuna Station was opened to traffic in that year. With the growth of railway facilities, many factories have moved into the Kashio Lowland from the coastal industrial zones near Kawasaki and Yokohama. Development of industry during World War I and II hastened industrialization.

Japanese industrial regions which were heavily damaged by bombing during World War II, have been restored since the 1950s. At the same time, the population of the Tokyo Metropolitan area increased. In Kanagawa Prefecture, the coastal industrial zones of Kawasaki and Yokohama were reconstructed first and industrialization spread to their outskirts. Further development of land for industrial use advanced into the flood plains of the Tsurumi and Kashio Rivers.

Industrial zones in the Kashio Lowland were linked together from Totsuka to Ofuna. Moreover, factory sites invariably consisted of high earth mounds so that water had less chance of stagnating in the lowland area. Concentration of population in big cities promoted land development for residential use. Some residential quarters composed of blocks of apartment houses were newly introduced to the Kashio Lowland.

Urbanized areas for 1962, 1968, 1973 and 1980, where urban land is used primarily for housing or industry, are shown in Fig. 2. If the ratio of urbanized area to that of the whole

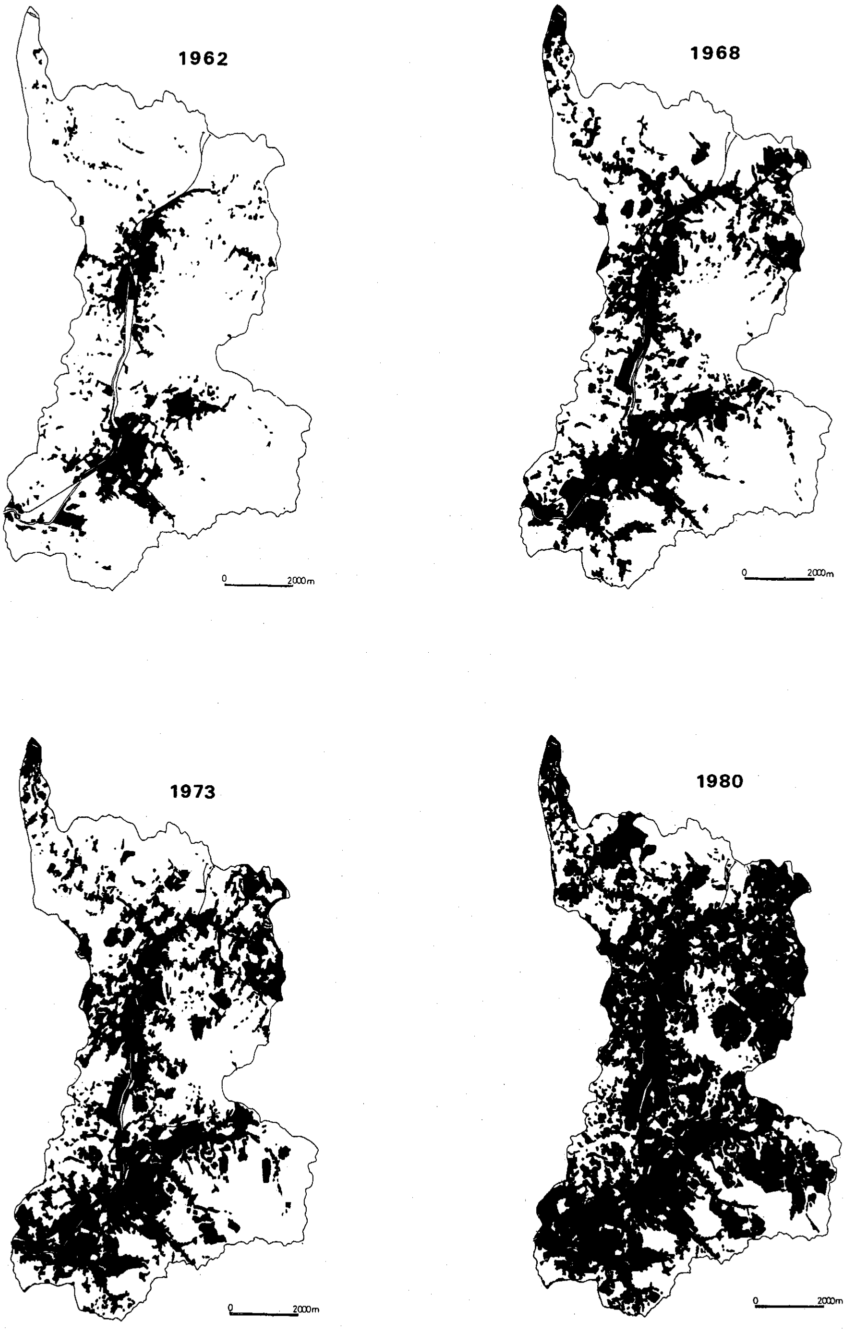

Fig. 2 Expansion of urbanized areas in the Kashio River basin (after Hashimoto, 1986)

river basin is defined as an urbanization ratio, this would be 14.5 % for 1962. Urbanization proceeded mainly by changes in land use in the Kashio Lowland — from paddy fields to residential or industrial areas — until the beginning of the 1960s. Urbanization ratios for each landform are shown in Table 2. While urbanized areas occupied 14.5 % of the whole river basin, 58.6 % were located in the alluvial lowlands, 26.2 % on the terraces and only 15.2 % in the hills. We notice that 38.7 % of the alluvial lowlands and 49.9 % of the terraces were urbanized but only 3.4 % of hills.

Land development in the hills accelerated around the middle of the 1960s in the Kashio River basin. Such land was parceled out in plots, some of which were sold for individual houses and others for collective high-rise apartments. Land development in the hills advanced with construction or improvement of traffic facilities (Fig. 3). A monorail was constructed between Ofuna and Nishikamakura in March, 1970 and extended to Enoshima in the next July. The Negishi Line which had been opened to traffic to Isogo was extended to Yokodai in March, 1970 and linked with the Tokaido and Yokosuka Lines at Ofuna in April, 1973. A branch line of the Sotetsu Line was opened to traffic

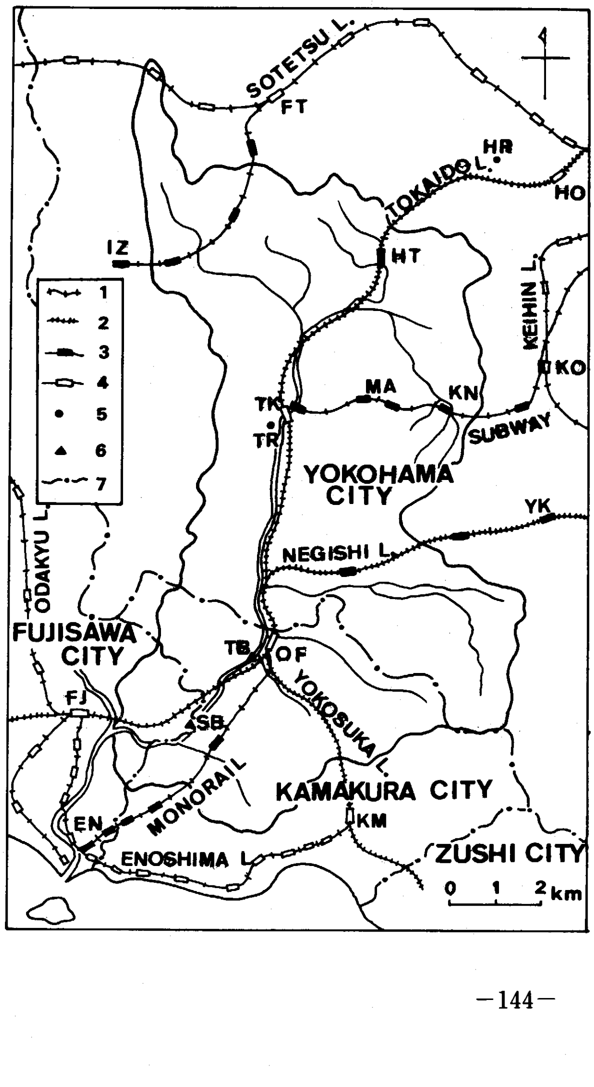

Fig. 3
Development of traffic facilities in and around the Kashio River basin
Legend: 1: Private railway, 2: National railway, 3: Railway station opened after 1970, 4: Railway station opened before 1960, 5: Rain station, 6: Water level station, 7: Boundary of local governments;
Rain stations: HR: Hodogaya rain station, TR: Totsuka rain station;
Water level station: SB: Shinko Bridge;
Railway stations: EN: Enoshima, FJ: Fujisawa, FT: Futamatagawa, HO: Hodogaya, HT: Higashitotsuka, IZ: Izumino, KM: Kamakura, KN: Kaminagaya, KO: Kamioka, MA: Maioka, OF: Ofuna, TK: Totsuka, YK: Yokodai.

from Futamatagawa to Izumino in April, 1976. A subway which was opened to traffic to Kamioka in December, 1972 was extended to Kaminagaya in September, 1976. This is going to be linked with the Tokaido and Yokosuka Lines at Totsuka in July, 1987. Except the monorail, all railways are bound for the Yokohama Station from where we can get to the Tokyo Station within 30 minutes. Such traffic facilities made it possible to shorten commuting time from the Kashio River basin to the central part of Tokyo as well as to that of Yokohama City.

Nozawa (1981) pointed out that 45 residential quarters were developed in the Kashio River basin from 1965 to 1967 and their total area reached 363 ha. Land development reached its peak between 1968 and 1970, and 69 residential quarters with a total area of 811 ha. were constructed in this period. Between 1971 and 1973, 301 residential quarters, that is, 307 ha. of the river basin, were parceled out. As a result, the urbanization ratio increased to 25.6 % in 1968, 42.9 % in 1973 and 56.8 % in 1980. An area of 3,544 ha. of the river basin was urbanized between 1962 and 1980. Of this, 2,755 ha were in the hills. The urbanization ratio for the hills is for 49.8 % in 1980 (Table 2).

The population of the Kashio River basin, calculated by totalling the population of each community, was 111,600 in 1960. It increased to 334,800 in 1970 and 446,400 in 1980. The latest datum shows that the Kashio River basin has 164,200 households and a population of 509,900 (Table 1).

Expansion of residential and industrial land use into the alluvial lowlands has increased flood damage potential. This is the main factor contributing to the increase in flood damage. The second is that urbanization in the hills has changed the rainfall-runoff system. Deforestation, extension of non-infiltrative surfaces, improvement of drainage facilities have all brought about an increase in volume of flood flow and have indirectly influenced the probability of occurrence of inundation in the alluvial lowlands.

3. Main Flood Hazards in the Kashio River Basin

The major 15 flood hazards since 1958 are listed in Table 3. The period of time in question was considered particularly significant since these hazards appeared after rapid urbanization took place in the Kashio River basin and they made clear the change of environmental conditions for flood hazards. A main cause of flood hazards before 1958 was weakness of facilities to prevent a flood, but this was replaced by the change in the rainfall-runoff system induced by urbanization in the hills after that year.

Table 2 Total area and urbanized area for each landform

Landform	Total Area (ha)	Urbanized Area (ha) 1962	1980
Hill	5,932 (70.8%)	201	2,956
Terrace	603 (7.2%)	301	551
Lowland	1,843 (22.0%)	713	1,252
Total	8,378	1,215 (14.5%)	4,759 (56.8%)

The inundation of September 26, 1958 was caused by Typhoon 22 (Kanogawa Typhoon). The total amount of precipitation reached 350 mm at Ofuna and Hodogaya. Maximum hourly precipitation was 39 mm. The Kashio River overflowed its banks and inundated most of the Kashio Lowland. Also, such tributaries as the Akuwa and Itachi rivers overflowed their banks. The number of households affected was 858 and these were located in Yokohama City in the Kashio River basin. Since the records for Kamakura and Fujisawa Cities only give a total number of households affected, it is impossible to extract the number of such households for the river basin area. The number of households shown as missing in Table 3 means that inundation occurred in the general area, but the actual number of households affected in the river basin is unknown.

Flood hazards caused by this typhoon threatened newly developed residential quarters in the whole Tokyo Metropolitan area, the Kashio River basin being situated at the southern end. These flood hazards proved how vulnerable newly-developed residential quarters are to flood hazards and showed that they were constructed without taking potential natural disasters of this kind into account. The term, "urban flood" has been in use since that occasion to describe similar inundations.

The damage that followed the heavy rain of June 28, 1961 exceeded the destruction caused by Typhoon 22. Total precipitation at Hodogaya was 213 mm, but it is noteworthy that, although the total amount of rainfall was less than that for Typhoon 22,

Table 3 Main flood hazards in the Kashio River basin since 1958

Date	Cause	Number of households affected			Water level at Tobe Bridge (m)	Precipitation at Totsuka (mm)	
		Yokohama	Kamakura	Fujisawa		Total	Max. (mm/h)
Sept. 26, 1958	Typhoon	858	MSG	MSG	MSG	350(O)	39(O)
June 28, 1961	Front	1,292	7,128	MSG	3.3	393(O)	MSG
June 27, 1965	Low	480	869	MSG	4.2	91(O)	MSG
June 28, 1966	Typoon	3,939	3,049	MSG	4.7(EST)	258	21
July 1, 1970	Front	546	461	MSG	4.0	124(O)	34
Aug. 31, 1971	Front	119	0	MSG	MSG	154	35(O)
Sept. 16, 1972	Front	327	35	MSG	3.9	181(H)	42(H)
Nov. 10, 1973	Front	3,226	2,875	MSG	4.3	174	45
July 8, 1974	Front	1,948	1,156	MSG	4.2(EST)	136	57
Nov. 7, 1975	Front	209	19	MSG	3.9	120	33
Sept. 11, 1976	Front	743	4	MSG	2.6	132	61
Sept. 10, 1977	Front	433	0	MSG	2.4	131(Z)	40(Z)
Mar. 29, 1980	Low	556	752	MSG	3.8	125(O)	MSG
Oct. 22, 1981	Typhoon	1,080	668	MSG	4.2	151(O)	MSG
Sept. 11, 1982	Typhoon	1,665	1,637	773	4.8	376	44

MSG : Data not available : EST : Estimated ; (O) : Ofuna ; (H) : Hongo ; (Z) : Okazu.
Data source :

Number of households affected in Yokohama City and precipitation between 1958 and 1977 follow Nozawa (1981).

Number of households affected in Kamakura City and water level at Tobe Bridge near Ofuna between 1961 and 1977 follow Kamakura City (1986).

Data since 1980 are given by each city office.

damage was actually greater. The number of households affected was, respectively, 1,292 and 7,128 in Yokohama and Kamakura cities in the Kashio River basin. The urbanization that had encroached into the Kashio Lowland suffered extensive damage. Between Totsuka and Kanai in the Kashio Lowland, flooding was limited to the left bank area, because provisional banking had been done along the right bank of the Kashio River after the floods accompanying Typhoon 22. Countermeasures against flood merely changed the area of inundation.

Maximum hourly precipitation was not large but precipitation brought by Typhoon 4 continued for hours on June 28, 1966. The total amount of precipitation reached 258 mm at Totsuka. Not only the main stream of the Kashio River but also its tributaries overflowed (Fig. 4). The number of striken households was 3,939 in Yokohama City in the Kashio River basin. Inundation near Ofuna flooded 2,960 households, most of which were in new housing areas developed after 1962. The total number of households affected reached 3,049 in Kamakura City in the Kashio River basin.

Though of short duration, heavy rainfall caused by a front drenched the Kashio River

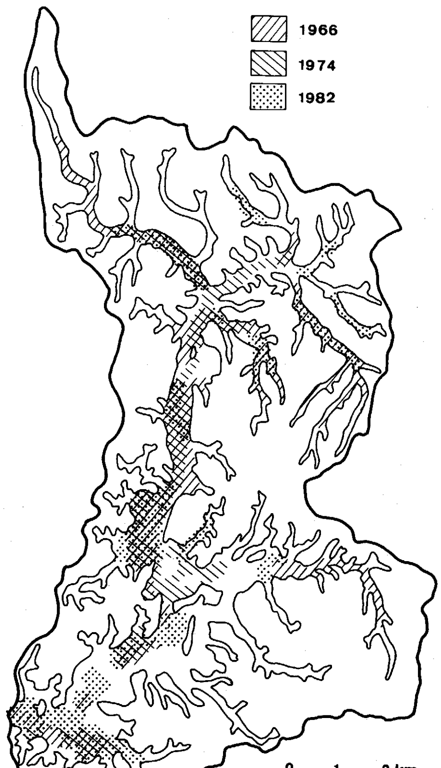

Fig. 4 Inundated area of the Kashio River basin due to recent floods

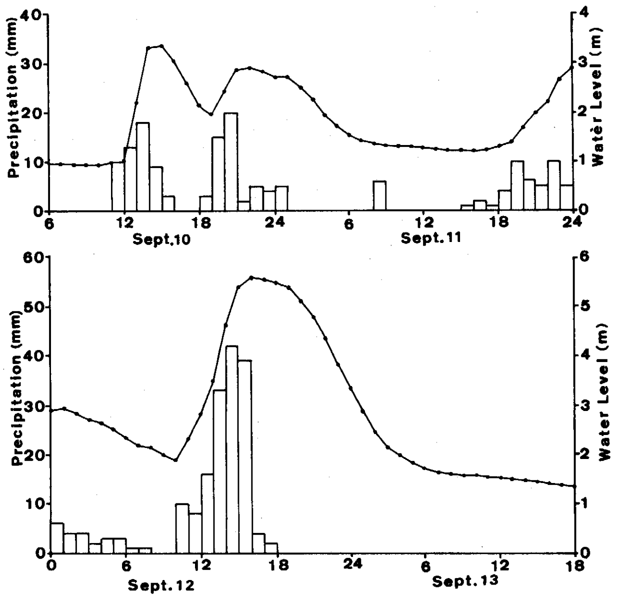

Fig. 5 Rainfall intensity at Hodogaya rain station and hydrograph at Shinko Bridge
Location of the stations is shown in Fig. 3.

basin on July 8, 1974. Maximum hourly precipitation was 57 mm at Hodogaya. A large quantity of rainwater was unable to drain away into the rivers, causing flooding in places. Also, the Kashio River overflowed its right bank near Totsuka (Fig. 4), the result, ironically, of "improvements" to the river course and banks and the reverse of what happened in the overflow of 1961.

Typhoon 18 brought much rain to the Kashio River basin from September 10 to 12, 1982. This typhoon was spawned near Guam Island on September 9 and moved northwards. It struck near Omaezaki in Shizuoka Prefecture and tore through northeastern Japan. As the typhoon approached Japan, the front which lay along the southern coast of Japan became active and rainfall began to fall around noon of September 10. Rainfall was weak and intermittent by the morning of the next day, but it intensified again in the evening. The heaviest rain fell from 14 to 15 o'clock of September 12. Collapse of slopes occurred at around 15 to 16 o'clock and the Kashio River overflowed at about 16 o'clock. Changes in hourly precipitation at Hodogaya and in water levels of the Kashio River at the Shinko Bridge are shown on Fig. 5. The total amounts of precipitation during the 3 days were 334 mm at Hodogaya and 376 mm at Totsuka. The highest water level of 5.57 m was recorded at 16 o'clock. There are 4 peaks in water levels. Of these, 3 were almost simultaneous with the high points in precipitation. This reflects a significant effect of urbanization on the rainfall-runoff system: a rise in water level takes so short a time. The number of households affected was 1,665 in Yokohama City, 1,637 in Kamakura City and 775 in Fujisawa City in the Kashio River basin. These figures are the largest in this decade.

Figure 4 shows the inundated areas of the 1966, 1974 and 1982 floods. Though some areas were inundated three times, inundation varied with each flood. Improvement of drainage facilities in one area affects the lower stream area. An embankment changes an overflow point. It is not easy to decrease inundation by improving drainage facilities. Construction of a discharge channel may well be thought of as a radical countermeasure.

4. History of Countermeasures for Flood Hazards

Urban land use began in the Kashio Lowland in 1889 when the Tokaido and Yokosuka Lines were opened to traffic. But the urbanized areas were restricted and most of the Kashio Lowland was used for paddy fields. With land readjustment works completed in 1910, the meandering Kashio River was straightened and continuous banks were constructed on both riparian zones. After that, urbanization gradually advanced in the Kashio Lowland with the construction of factories and development into a residential area. But countermeasures for flood hazards were not earnestly pursued because of World War II.

Flood prevention works after World War II began with a relief work for the unemployed in 1951, but improvement of banks and riverbeds was undertaken in only limited areas (Nozawa, 1981). The flood hazards caused by Typhoon 22 of 1958 required real flood prevention works. After that, a bank was constructed between Totsuka and Kanai along the right riparian zone of the Kashio River. As mentioned in the last chapter, this work, too, was a provisional one, and inundation occurred again in 1961. However, the right bank area escaped inundation. With this as a turning point, a flood prevention scheme was planned anew and work began in 1963. The riverbed was widened and the riverwalls were improved in the whole Kashio Lowland. An hourly rainfall of 35 mm and a runoff coefficient of 0.56 were adopted for this plan.

Urbanization of the Kashio River basin, however, advanced much faster than flood prevention works and heavier flood hazards occurred in 1966. The left riverwall was improved between Totsuka and Kanai by 1969 and the riverbed was widened to 39 m. These works induced inundation of the right bank area in 1974, because the right bank had not been improved since the provisional improvement done after the flood hazards of 1958.

The main purpose of flood prevention works undertaken in Japan before 1978 was to enable rainwater to flow rapidly to the sea. Accordingly, riverbeds were widened and deepened and banks were raised to a higher level so as to increase the flow of water. Riparian slopes and riverbeds were sealed by concrete blocks in order to decrease a coefficient of roughness. These works affected the rainfall-runoff system. On the other hand, urbanization advanced without keeping pace with advancement of flood prevention works. Thus the general effect of urbanization was to caused floods to strike more swiftly and to rise to higher levels than before. Also, urban development in a small river basin made it impossible to widen a riverbed in a lower course area. It became to be very hard to prevent flood hazards by improving river courses. Then the Ministry of Construction asked the Commission on River Administration to study a new basic premise of integrated flood prevention. The Commission proposed a integrated flood prevention scheme in 1978, which includes flood control and flood plain management. Practical application of integrated flood prevention started in 1978 and is now under execution in 14 river basins. Intense urbanization, rapid increase of population and frequent occurrence of inundation are common in all these river basins (Nakano *et al.,* 1986). The Sakai River including its tributary of the Kashio River basin has been targeted for incorporation into the scheme since 1980. In this year, the council for deliberating measures for flood prevention in the Sakai River basin was set up with the participation of the local governments concerned. A flood prevention plan was determined in 1981, in which a rainfall of 50 mm/h was adopted as a planning criterion. The plan stipulates that improvement of a river course and construction of a rainwater reservoir and of a water discharge channel will accomodate inundation due to an hourly rainfall of 50 mm by 1990.

On the other hand, to avoid increasing the amount of flood discharge, it is necessary to control development in the hills and to restore rainwater there. Yokohama City has enacted legislation on Technological Standards for Urban Development that requires a developer to construct a rainwater-control reservoir where the development area is broader than 1 ha, or a rainwater-control pond for an area of less than 1 ha (Table 4). Kamakura and Fujisawa Cities have the same standards. There are 140 rainwater-control reservoirs set up in the development zones of more than 1 ha, in the Kashio River basin. They can contain a total volume of 927,826 m^3 of rain water and their total draining area attains to 1,275 ha. That means that rainwater falling in about one fourth of the urbanized area is forced to go through the rainwater-control reservoirs.

Table 4 A design standard for a flood control reservoir

Development area	more than 15 ha	5 ha to 15 ha	0.3 ha to 5 ha	less than 0.3 ha
Intensity of rainfall	50mm/h	40mm/h	30mm/h	30mm/h
Duration of rainfall	2 h. 30 m.	3 h.	3 h.	1 h. 30 m.
Pondage	750m^3/ha	720m^3/ha	540m^3/ha	270m^3/ha

5. Concluding Remarks

Taking the Kashio River basin as an example of a river basin which has been rapidly urbanized since the 1960s, relationships between urbanization and flood hazards has been historically summarized. The historical change of conditions for flood hazards can be divided into several stages as follows:

(1) The period when the natural conditions of the river basin were not largely changed by human works (before 1907).

This is the period before readjustment of arable land was carried out. Lowlands were used for paddy fields and banks to the Kashio River were constructed only in selected areas. Because main land use in the Kashio Lowland was paddy fields, a flood did not usually cause extensive damage.

(2) The period when the river course was artificially changed and urbanization began in

the river basin (from 1907 to World War II).

On the basis of the law concerning readjustment of arable land, the meandering river course was straightened and continuous banks were constructed along both riparian zones of the river to protect paddy fields from inundation and to enable arable land to be used more effectively. The possibility of a decreased danger of inundation, however, gave rise to more intensive land use such as industry, for example, would require, and many factories went to the Kashio Lowland. At the same time, because Japan was preoccupied with World War II, countermeasures for flood hazards were not considered.

(3) The period of increased urban flood potential (after World War II to around 1958).

With Japan's postwar rehabilitation, industrial regions have been redeveloped. Industrialization has spread out into surrounding areas. Many factories have come to the Kashio Lowland from the Keihin industrial region. The ground level of land for industrial use was raised so as to prevent inundation and water storage capacity decreased in the Kashio Lowland. Development of industry led to the concentration of population in the Tokyo Metropolitan area, and the Kashio Lowland was targeted for residential quarters, too. As a result, there has been a growth in flood damage potential. Anxiety over this was exacerbated by the flood of 1958.

(4) The period of the introduction of regular countermeasures for flood hazards (from 1958 to 1980). These measures unfortunately could not keep pace with urbanization.

With the flood of 1958 as a turning point, regular countermeasures for flood hazards were introduced. After the flood of 1961, countermeasures for the whole river basin were planned and flood prevention works were begun. But flood prevention works for decreasing flood hazards were outpaced by urbanization, so that flood hazards could usually be expected annually. Also urbanization was not limited to the Kashio Lowland; large-scale residential quarters were also constructed in the hills. Urban development thus created two problems which needed to be resolved. The first question was, what could be done to prevent the river flooding in the alluvial lowlands. The second question was, how one could control the rainfall-runoff system in the hills.

(5) The period of implementation of comprehensive countermeasures (since 1980).

It is very hard to prevent inundation by improving flood prevention facilities so as to counterbalance the increased runoff, because a runoff ratio has increased significantly through intensified urban land use in the hills and intensive land use in the alluvial lowlands has also made it impossible to obtain land for widening riverbeds. Accordingly, it is necessary to decrease runoff of rainwater throughout the whole river basin. Japanese policy for preventing urban floods has changed and comprehensive countermeasures for flood hazards have been adopted since 1978. The policy has been applied to the Sakai River since 1980 and also includes the Kashio River.

(6) Kashio River in the future.

The Flood Prevention Plan of the Sakai River basin was made by the council for deliberating measures for flood prevention in the Sakai River basin in 1981. In this plan, a 50 mm/h rainfall at recurrent intervals of about 5 years was provisionally adopted as the planned rainfall. The peak discharge of the Kashio River caused by rainfall of this intensity is supposed to be 460 m^3/sec at the junction with the Sakai River. However, the desirable design flood discharge of the Kashio River at this point is 1,050 m^3/sec. Such a flood discharge is supposed to occur once in a hundred years. It is impossible to maintain a flow of water of 1,050 m^3/sec so as to avoid inundation in the Kashio Lowland. If flood prevention works have to counterbalance such a huge flood discharge, construction of a new drainage canal is indispensable. This canal will consist of a tunnel because land for an open-cut canal will not be available in the Kashio River basin. The tunnel will pass under a watershed. Examples of such a drastic countermeasure as transformation of a river basin can be seen in many river basins in Japan. For example, a drainage tunnel was constructed in the Oka River basin in Yokohama City. A twostoried riverbed exists along the Kanda River in Tokyo. Construction of a drainage canal is usually adopted as the most effective countermeasure for flood hazards caused by a big river. However, a drainage canal becomes to be indispensable for flood prevention in even a small river basin in Japan. This means that land development is so intensive that a small river has to burden huge flood discharge beyond its capacity.

The change once added to the land becomes the threshold condition for later development or countermeasures for disasters. Artificial change of land characteristics does not reverse the trend. Non-reversible changes pile up. To preserve the function of storing rainwater characteristic of alluvial lowlands, raising the ground level by banking is restricted in the river basin where comprehensive countermeasures for flood hazards have been adopted. But it is impossible to remove fills already banked in an alluvial lowland. Transformation of flood hazards such as that caused by the development of urban areas in the Kashio River basin is common to all rivers flowing in urban areas in Japan. The cycle of flood hazards and countermeasures is, and will remain, a vicious circle as long as development of the river basin continues.

The author would like to express his gratitudes to Mr Mitsuru Hashimoto and Mr Jun Takahashi for their assistance in data arrangement. Gratitude is expressed to Mr Hirofumi Akiyama for drawing Figs. 1 and 4. I would like to dedicate this report to the late Professor Yoshio Watanabe, who continually encouraged my study of urban areas.

References Cited

Hashimoto, M.(1986): *Ryuiki no Kaihatsu to soreni tomonau Suigai no Henyo (Land Development in River Basins and Its Effects to Flood Hazards),* unpublished MS thesis*.

Kamakura City Office (1986): *Naisui Haijo Taisaku Keikaku Sekkei (A Plan for Preventing Inundation due to Rainwater)*, 196p.

Nakano, T., Matsuda, I. and Takahashi, Y.(1986): Floodplain management: a general discussion based on regional studies. *Geographical Reports, Tokyo Metropolitan University,* 21, 261-273.

Nozawa, T.(1981): Kashiogawa chisui kou (Study on flood prevention works in the Kashio River basin). In Yokohama City Office (ed.): "*Yokohamashinai no Kasen Kankyo (Environment of Rivers in Yokohama City)*", 115-199*.

(* in Japanese)